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PROGRESS IN THE GLOBAL STANDARDIZATION OF GRAVITY: AN ANALYSIS --ETC(U)

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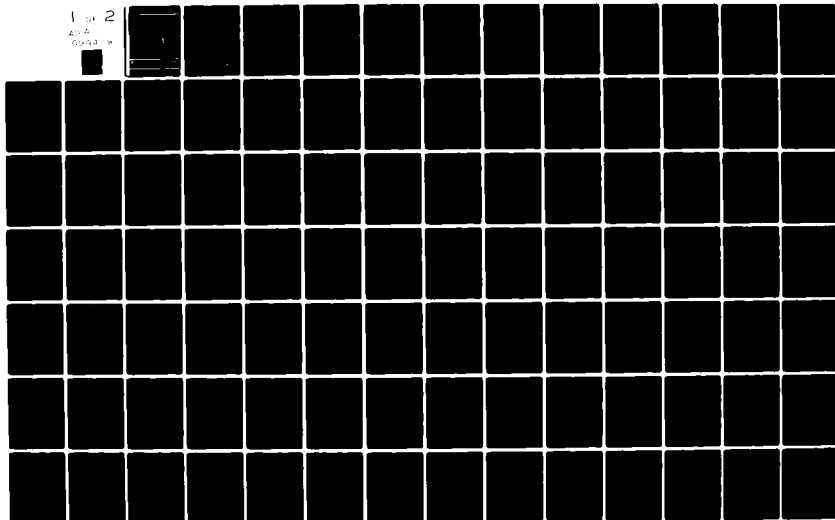
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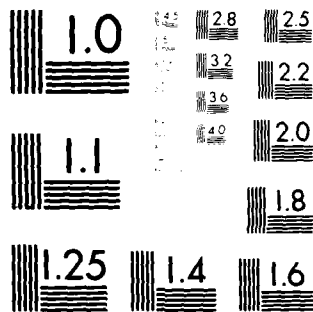
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**PROGRESS IN THE GLOBAL STANDARDIZATION OF GRAVITY:  
AN ANALYSIS OF THE  
WOOLLARD AND ROSE INTERNATIONAL GRAVITY VALUES**

**GEORGE P. WOOLLARD and VALERIE M. GODLEY**

**DECEMBER 1980**

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## ABSTRACT

The history of improvements in the global standardization of gravity values since the advent of high range gravimeters in 1948 is reviewed. In particular the gravity base values given in SEG special publication International Gravity Measurements (Woollard and Rose, 1963) are evaluated against the most recent set of standardized gravity base values, The International Gravity Standardization Net, 1971 (Morelli et al, 1974). Adjunct IGSN 71 values prepared by the U.S. Defense Mapping Agency Aerospace Center (unpublished) are also used to give a more comprehensive worldwide comparison of values. The results for 787 comparisons of Woollard and Rose (1963) values and IGSN 71 values for the same sites indicate that, in general, there is no difference in gravity standard represented. However, there is a mean absolute datum difference of 14.7 mgal (standard deviation 0.25 mgal). As this value is the same as the difference in the IGSN 71 value for the Woollard and Rose primary base value at Madison, Wisconsin, it corroborates the independent assessment that there is, in general, no difference in gravity standard. However, examination of the data by geographic areas indicates that there are areal anomalous offsets in datum due presumably to undetected tares in the Woollard and Rose values, and also a departure in gravity standard of 0.2 mgal per 1000 mgal in both South America and Europe. As it was possible to establish specific areas in which the Woollard

and Rose values are in apparent error relative to the IGSN 71 values as well as the nature and magnitude of the differences in values, it appears possible to use the more extensive worldwide network of Woollard and Rose base values to extend the IGSN 71 network with, in general, an absolute reliability of the order of  $\pm 0.15$  mgal. As many of the existing gravity surveys are not tied to IGSN 71 bases, but are tied to Woollard and Rose bases, much of the existing gravity data in the world not on the new IGSN 71 gravity system could thus be integrated into the new international gravity system with sufficient reliability for most purposes. However, more precise gravity values on an absolute basis are required if gravity is to play a significant role in studying global tectonic movements and geodynamic processes.

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## INTRODUCTION

Gravity standardization, although a concern of geodesists for more than three fourths of a century, was a topic of little interest to other earth scientists for many years, and of even less concern to exploration geophysicists until very recently. What has made the standardization of gravity become increasingly important are the following: (1) the recognition of the importance of gravity in understanding regional changes in crustal and upper mantle structure, surficial geology and the distribution and occurrence of all mineral deposits and not just those related to energy; (2) recognition of the fact that we are living on a dynamic earth whose pattern of on-going tectonic horizontal and vertical movements can be detected locally, regionally and globally through secular changes in gravity. Without gravity standardization, the value of gravity in such investigations is limited; but with standardization, gravity becomes a key method for studying such problems. The fact that high precision observations are (1) relatively inexpensive; (2) there exist large bodies of gravity data that can be standardized to useful levels of absolute reliability for such studies and (3) there now exist a world network of gravity standardization bases having an absolute reliability of better than 0.1 mgal, all indicate support and expansion in the role of gravity in both advancing scientific knowledge and applying this knowledge to the benefit of man. This paper represents one step in the process of standardizing the world's gravity data.

## HISTORICAL BACKGROUND ON GRAVITY STANDARDIZATION

The global standardization of gravity started with the Vienna System adopted in 1900, which was estimated to have an absolute reliability of about  $\pm 10$  mgal. The adoption of the Potsdam reference system in 1909, however, resulted in a -16 mgal correction in the Vienna absolute gravity datum. Other than this action and interconnections of national gravity bases to Potsdam with pendulums having variable reliability, there were few significant advances in the global standardization of gravity until 1947 when a new era in gravity standardization can be said to have started. The significant event in 1947 was the development of the Worden high-range gravimeter, which permitted gravity observations to be made on a global basis with a reliability of better than 1 mgal. This instrument, which Sam P. Worden built for the writer on a "no work--no pay" basis, was tested in 1947 on a semi-global series of leap-frog measurements to evaluate drift stability and repeatability of values (unpublished), and then used in 1948 for an around-the world- series of observations at 33 primary and secondary national gravity bases as well as for the establishment of some 150 new globally distributed gravity bases (Woollard, 1950). These measurements demonstrated that uncertainties in national gravity base values, that at the time were of the order of 2 to 5 mgal (Morelli, 1946; Hirvonen, 1948) and in one case exceeded 30 mgal, could be resolved to better than 1 mgal with gravimeter measurements. This first series of gravity observations with the Worden gravimeter, and the relatively low budget required as compared to pendulum measurements, as well as the

significant difference in time required in making a series of world-wide gravity observations, initiated a period of intensive gravity investigations on a global scale. It was attended by continuous improvements in gravity instrumentation (gravimeters, pendulums and absolute gravity apparatus); a significant increase in the numbers of investigators making international and inter-continental gravity measurements and resulted in a marked improvement in gravity standardization. One product of the work done by the writer and his students during the period (1948-1962) was SEG special publication International Gravity Measurements (Woollard and Rose, 1963). This publication represented a compendium of global gravity values and site descriptions for some 100 primary gravity bases established with pendulums and more than 1200 auxiliary gravity bases established with gravimeters. At the time (1963) it represented the most comprehensive and successful attempt to establish a reliable international gravity standard and to cover the world with a network of gravity bases whose values were all on the same datum and gravity standard. This publication also included comparative analyses of not only the national gravity base station values that were in use, but also values being obtained by all other investigators making modern high-range pendulum and gravimeter measurements, with particular emphasis on the differences in gravity standard represented. Although a complete analysis could not be made at the time regarding the absolute reliability of the Woollard and Rose (1963) gravity values, on the basis of comparisons with the values that had been adopted in 1959 by the International Association of Geodesy and the International Gravimetric Bureau in Paris (IBG) for the



then designated 34 fundamental international gravity bases, the Woollard and Rose (1963) gravimeter values had a mean overall absolute reliability of the order of  $\pm 0.3$  mgal. The actual differences brought out by these comparisons of values, which were possible at 32 of the 34 designated fundamental bases and which covered a range of over 3000 mgal, indicated agreement to better than  $\pm 0.2$  mgal at 50% of the sites, and  $\pm 0.35$  mgal at 75% of the sites.

Another value of the work of Woollard and Rose (1963), moreover, was that it brought into focus problems regarding the international standardization of gravity and their possible solutions. It was this aspect of the work that set the stage for the follow-up World Gravity Standardization Program (Szabo, 1963), whose results are incorporated in the most recent attempt to standardize gravity, The International Gravity Standardization Net 1971 (Morelli et al, 1974). The gravity values given by Morelli et al (1974), referred to here as IGSN 71, incorporate a change of  $-14.0$  mgal in the Potsdam absolute gravity datum and  $-14.9$  mgal in the value adopted for the Bad Harzburg datum used as an alternate for Potsdam during the period (1939-1963) when western observers were not able to make observations at Potsdam. The IGSN 71 values also incorporate an improvement in gravity standard over that which, in general, it had been possible to establish with relative gravity pendulum measurements and early absolute gravity determinations. This improvement resulted from the development of a laser interferometer free-fall absolute gravity apparatus by

Faller, (1965) which was sufficiently portable to permit measurements with the same apparatus at points as widely separated as Fairbanks, Alaska and Bogota, Colombia. It was the observations made with the Faller apparatus between these end points, representing over 4800 mgal change in gravity (Hammond and Faller, 1971), that defined in large measure the IGSN 71 gravity standard. Another factor contributing to the reliability of the IGSN 71 values was the redundancy in data available, and some 25,000 modern gravity observations interconnecting the 473 primary gravity bases and their excenters were used in the IGSN 71 adjustments reported by Morelli et al (1974).

The IGSN 71 values are thus on a different absolute datum from the Woollard and Rose and other earlier gravity values, and should be significantly superior in terms of the gravity standard represented, as well as have a higher degree of reliability on a relative basis. The absolute reliability of the IGSN 71 values world-wide as defined by the statistical tests made by Morelli et al (1974) is better than  $\pm 0.05$  mgal.

To test the actual degree of improvement represented in the IGSN 71 values of Morelli et al (1974), the writer compared the IGSN 71 values and the Woollard and Rose (1963) values at the same IGB fundamental gravity bases used originally by Woollard and Rose to define the probable absolute reliability of their values. This comparison (presented in the next section) after allowing for the 14.7 mgal difference in the IGSN 71 value for the Madison, Wisconsin base datum used for the Woollard and Rose

values showed: (a) no difference in gravity standard from that incorporated in the IGSN 71 values, and (b) that at 58% of the 32 fundamental gravity base sites for which there are comparative data agreement was within  $\pm 0.1$  mgal, and that at 80% of the sites the agreement was better than  $\pm 0.2$  mgal. These results, substantiated in the next section of this paper, thus indicated the Woollard and Rose values were better than was originally estimated ( $\pm 0.3$  mgal) and only approximately 0.15 mgal inferior in relative gravity reliability to the IGSN 71 values at better than 75% of the IGB designated fundamental world gravity base sites.

This finding, plus the fact that the IGSN 71 values of Morelli et al (1974) only cover about 550 geographic localities with a heavy emphasis on places in Europe (in contrast to the more extensive world-wide coverage of the Woollard and Rose values) led to this present paper.

#### OBJECTIVES ADDRESSED AND METHOD OF ANALYSIS

The primary objectives of the present paper are as follows:

1. To determine if the Woollard and Rose (1963) values do define a gravity standard that conforms everywhere to the absolute standard incorporated in the IGSN 71 values, and if not, where are the departures and what is their magnitude.
2. Are there places where there are significant offsets in datum other than the Madison, Wisconsin base datum offset of 14.7 mgal between the Woollard and Rose (1963) values and the IGSN 71 values, and if so where, and what is the magnitude of the datum shifts.

3. Are there places where there are erratic differences in the two sets of values, and if so what areas are involved and what is the magnitude of the differences.

4. Is it feasible in the light of the above to adjust the Woollard and Rose values to the IGSN 71 gravity standard and datum with a sufficient degree of reliability to in effect extend the global coverage of the IGSN 71 standardization net even though the degree of reliability of the added sites might be 0.1 to 0.2 mgal less than the IGSN 71 values of Morelli et al (1974).

In approaching the above objectives, the gravity standard in each continental area as defined by the Woollard and Rose (1963) gravimeter values at pendulum sites will be examined first. The gravimeter values are used rather than the pendulum values since the quality of the pendulum measurements on a station-to-station basis varied with the area depending on the degree of improvement that had been incorporated in the pendulum apparatus at the time of the observations, whereas the gravimeter measurements were adjusted, insofar as possible at the time, to a single gravity standard. This standard was that defined by the series of pendulum measurements over the North American Rocky Mt. Front calibration range, where three sets of repeat pendulum observations provided a "best" set of gravity standardization values between Point Barrow, Alaska and Mexico City, Mexico.

The comparison of values at all sites in each geographic area to determine the degree of agreement between the Woollard and Rose values and the IGSN 71 values is considered independently from that at the pendulum gravity standardization bases. The reason

for making this division of the analysis (the standardization bases versus all bases in an area) is because in order to have a maximum number of comparative values for an area, and hence more comprehensive analysis, IGSN 71 values other than those of Morelli et al (1974) have to be used. The adjunct IGSN 71 values used by the writer are the unpublished values derived by the U.S. Department of Defense Mapping Agency Aerospace Center (DMAAC), which cover about 65% of the Woollard and Rose gravimeter base sites (airports, etc.) that are not related as excenters to the pendulum observation sites. Although, in general, the difference between the IGSN 71 values as determined by Morelli et al (1974) and DMAAC for the same site does not exceed 0.04 mgal, and there is agreement to  $\pm 0.01$  mgal for 67% of the 239 comparisons that could be made, it was found that there are systematic differences between the two sets of IGSN 71 values. These change in both magnitude and sign in going from one continental area to another, and in addition there are offsets in datum between the continental areas. These differences in the IGSN 71 values (Figure 1), while not significant in making an overall evaluation of the Woollard and Rose values, were judged to be sufficiently significant in evaluating the gravity standard incorporated in the Woollard and Rose values at the primary (pendulum) gravity standardization bases to restrict the IGSN 71 values used for this purpose to those of Morelli et al (1974). These values aside from there being the "official" IGSN 71 values also have the advantage of including the pendulum base excenter site values used in lieu of the pendulum base values, whereas the DMAAC IGSN 71 values do not.

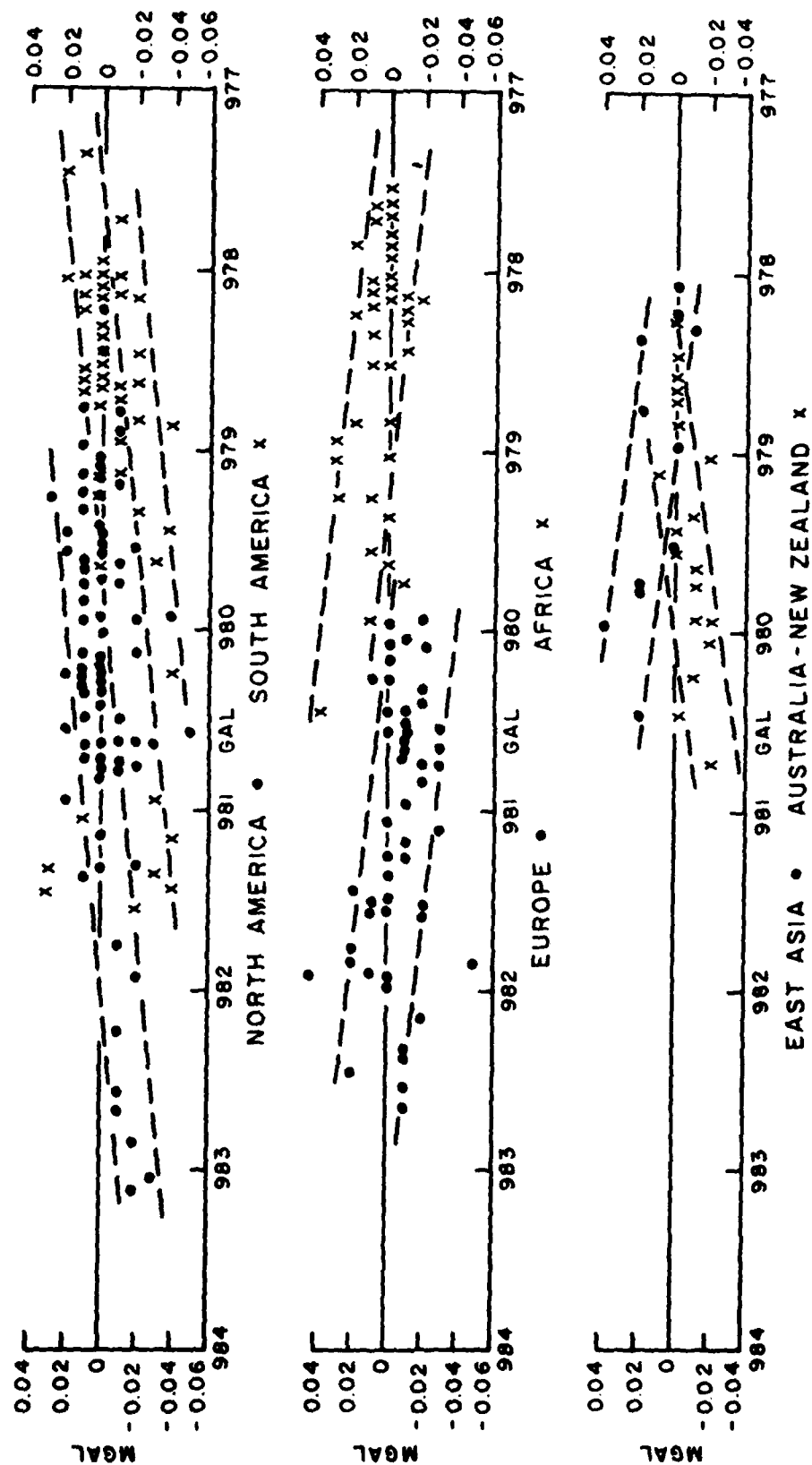


Fig. 1. Comparison of IGSN 71 values as determined by the Defense Mapping Agency Aerospace Center relative to the IGSN 71 values of Morelli et al. (1974).

Because of the extensive number of tables of comparative values involved, these are not included as part of this paper and only graphical representations of differences in values are presented. However, complete tabulations of values by area listed according to the Woollard and Rose (1963) site designation system are available from the SEG office in Tulsa, Oklahoma.

THE EVALUATION OF THE IMPROVEMENT IN GRAVITY STANDARDIZATION  
INDICATED AT THE IGB FUNDAMENTAL WORLD GRAVITY BASE SITES

As brought out earlier, the absolute reliability of the Woollard and Rose (1963) gravity values was originally defined as being about  $\pm 0.3$  mgal on the basis of comparisons with the values adopted for the IGB designated fundamental gravity bases. The datum for the IGB values was that for Bad Harzburg, West Germany (980.1804 gal), which had been adopted as an alternate datum for Potsdam because Potsdam was closed to western observers during World War II and later as a result of the partitioning of Germany. The Woollard and Rose (1963) values, although based on Madison, Wisconsin for datum control were on essentially the same datum as the IGB values since the Woollard and Rose value for Bad Harzburg (980.1803 gal) differs by only 0.1 mgal from the IGB value. As this difference is within the degree of uncertainty in both sets of values, it cannot be regarded as significant. Although earlier attempts to standardize gravity values internationally, such as those of Morelli (1946) and Hirvonen (1948), had not considered Bad Harzburg, they had included quite a number of the other IGB fundamental gravity bases, and since one aspect of the paper is to define the history of improvement in gravity standardization,

these values will also be considered in this section along with the IGB (1959) values in determining the degree of improvement in gravity standardization prior to and since the publication of the Woollard and Rose (1953) values. In all cases, the IGSN 71 values of Morelli et al (1974) are used as a standard for comparison.

The comparative values listed in Table 1 are representative of the tables included in this report as Appendix I and Appendix II. Because of the restrictive number of comparisons for the Morelli (1946) and Hirvonen (1948) values at IGB fundamental gravity bases, their values for Copenhagen and Stockholm are used to give a more representative set of comparisons for these two sets of adjusted values.

As seen from Table 1, the Morelli (1946) adjusted values show considerable difference from the IGSN 71 values (12.1 to 17.4 mgal). If the difference in datum value at Potsdam (14.0 mgal) is allowed for, the differences range from + 2.0 mgal to - 3.4 mgal. However, the distribution of these differences in values is skewed toward values greater than 1.2 mgal. By coincidence this value (1.2 mgal) corresponds to the degree of apparent reliability for 50% of the 15 comparative values. On the basis of 75% of the values, the agreement is only better than 2.6 mgal.

The Hirvonen (1948) adjusted values show a more normal distribution of differences relative to the IGSN 71 values after allowing for the 14.0 mgal difference in datum. Fifty percent of the values agree to better than 1.2 mgal with the IGSN values and 75% to better than 2.2 mgal. These two early adjustments therefore did not differ a great deal in terms of their overall reliability



Table 1

Comparison of IGSN 71 values at ICB World Fundamental Gravity Bases with Earlier Determined values.

	(1) IGSN 71	(2) Morelli 1946	(3) 1-2 mgal	(4) Hirvonen 1948	(5) 1-4 mgal	(6) IGB 1959	(7) 1-6 mgal	(8) Woollard Rose 1963	(9) 1-9 mgal	(10) 9-14.7 mgal
<b>EURO-AFRICA BASES</b>										
Reykjavik, Natl Base	982.2650					.2785	-13.5	.2800	-15.0	-0.3
Oalo GW-65	981.9126	.9280 <sup>+</sup>	-15.4			.9284	-15.8	.9272	-14.6	+0.1
Helsinki, Natl Base	981.9006	.9164	-15.8	.9158	-15.2	.9152	-14.6	.9152	-14.6	+0.1
Stockholm, Natl Base*	981.8314	.8466	-15.2	.8475	-16.1			.8463	-15.1	-0.4
Copenhagen, GW-64*	981.5430	.5584	-15.4	.5575	-14.5			.5577	-14.7	0.0
Teddington, GW-67	981.1818	.1960	-15.2			.1960	-14.2	.1966	-14.8	-0.1
Bad Harzburg, GW-63	981.1655					.1804	-14.9	.1803	-14.8	-0.1
Paris, OBS-A	980.9287	.9461*	-17.4	.9435	-14.8	.9437	-15.0	.9436	-14.9	-0.2
Rome GW-61	980.3492	.3663	-17.1	.3663	-17.1	.3637	-14.5	.3639	-14.7	0.0
Lisbon, GW-110	980.0757	.0885	-12.8	.0876	-11.9	.0915	-15.8	.0903	-14.6	+0.1
Madrid, OBS base	979.9665	.9830	-16.5	.9807	-14.2	.9810	-14.5	.9812	-14.7	0.0
Beirut, Fac. Med.	979.6763					.6910	-14.7	.6909	-14.6	+0.1
Khartoum, Camb. Base	979.2886					.3033	-14.7	.3033	-14.7	0.0
Dakar, GW-111	978.3703					.3880	-17.7	.3852	-14.9	-0.2
Leopoldville, GW-113	977.8998					.9185	-18.7	.9146	-14.8	-0.1
Johannesburg, GW-73	978.5355					.5495	-14.0	.5495	-14.0	+0.7
Capetown, GW-74	979.6327					.6472	-14.5	.6473	-14.6	+0.1
<b>AMERICA BASES</b>										
Fairbanks, GW-6	982.2317					.2452	-13.5	.2462	-14.5	+0.2
Vancouver, P.O. Base	980.9207					.9370	-16.3	.9352	-14.5	+0.2

+ corrected by 10 mgal for topographical error in Morelli (1946).

\* Not designated ICB fundamental bases but included for Morelli (1946) and Hirvonen (1948) comparisons.

Table 1 continued.

AMERICA BASES (cont.)									
	(1) IGSN 71	(2) Morelli 1946	(3) 1-2 mgal	(4) Hirvonen 1948	(5) 1-4 mgal	(6) IGB 1959	(7) 1-6 mgal	(8) Woollard & Rose 1963	(10) 9-14.7 mgal
Ottawa, GW 53-A	980.6061	.6210	-15.9	.6625	-16.4	.6220	-15.9	.6208	-14.7 0.0
Madison, GW-3	980.3542					.3689	-14.7	.3689	-14.7 0.0
Washington, U337, Natl base	980.1043	.1180	-13.7	.1191	-14.7	.1190	-14.7	.1188	-14.5 +0.2
Mexico City, GW-43	977.9265	.7417	-15.2			.9415	-15.0	.9414	-14.9 -0.2
Panama, GW-92	978.2267					.2410	-14.3	.2417	-15.0 -0.3
Quito, GW-94	977.2632					.2805	-17.3	.2777	-14.5 +0.2
Rio de Janeiro GW-109	978.7899	.8020	-12.1			.8060	-16.1	.8047	-14.8 -0.1
Buenos Aires, GW 98-A	979.6900					.7046	-14.6	.7048	-14.8 -0.1
PACIFIC -ASIA BASES									
Kyoto, GSI Base	979.7073					.7215	-14.2	.7216	-14.3 +0.4
New Delhi, GW-5a	979.1216					.1362	-14.6	.1363	-14.7 0.0
Honolulu, GW 55	978.9384					.9526	-14.2	.9530	-14.6 +0.1
Singapore, GW 102-A	978.0660					.0820	-16.0	.0810	-15.0 -0.3
Melbourne, GW 83	979.9652	.9880	-12.8			.9790	-13.8	.9797	-14.5 +0.2
Christchurch, GW 81	980.4943					.5095	-15.2	.5089	-14.6 +0.1
Average without regard to sign									0.16 mgal
Average with regard to sign									+0.012 "

NOTE: GW prefix is pendulum observation site number designation in Woollard and Rose (1963).  
Woollard and Rose values (col. 8) are gravimeter values at all sites.

Datum adjustments to IGSN 71 values:

Morelli (1946) -14.0 mgal  
Hirvonen (1948) -14.0 mgal  
IGB (1959) -14.9 mgal  
Woollard and Rose (1963) -14.7 mgal. See column (10) of table.

relative to the IGSN 71 values.

The IGB (1959) adopted values, after allowing for the 14.9 mgal difference in datum at Bad Harzburg relative to the IGSN 71 value for this site, indicate a reliability of better than 0.6 mgal for 50% of the values and 1.1 mgal for 75% of the values. These values, therefore, represent a significant advance in standardizing gravity in the interim period 1948-1959. The Woollard and Rose (1963) values, as indicated earlier, after allowing for the 14.7 mgal difference in datum at the Madison, Wisconsin base relative to the IGSN 71 value for Madison, however, show agreement with the IGSN 71 values to better than 0.1 mgal at 58% of the sites, and to better than 0.2 mgal at 82% of the sites.

As the above differences in values do not give an indication of any bias in sign, the differences with regard to the sign of the correction required to have all values consistent with the IGSN 71 correction for the datum used are shown as distribution plots in Figure 2. Because of the small sample represented in the Hirvonen (1948) values, these are omitted. As seen from Figure 2-A, the datum corrected Morelli (1946) values have a marked bias and the central tendency is centered at - 1.2 mgal, indicating that on average the values would require a correction of -15.2 mgal to agree with the IGSN 71 values rather than -14 mgal, which is the Potsdam datum correction. The IGB values (Figure 2-B) define a central tendency centered at +0.2 mgal, indicating that the mean correction in adjusting these values to the IGSN 71 datum is -14.7 rather than the datum correction of -14.9 mgal that applies to Bad Harzburg.

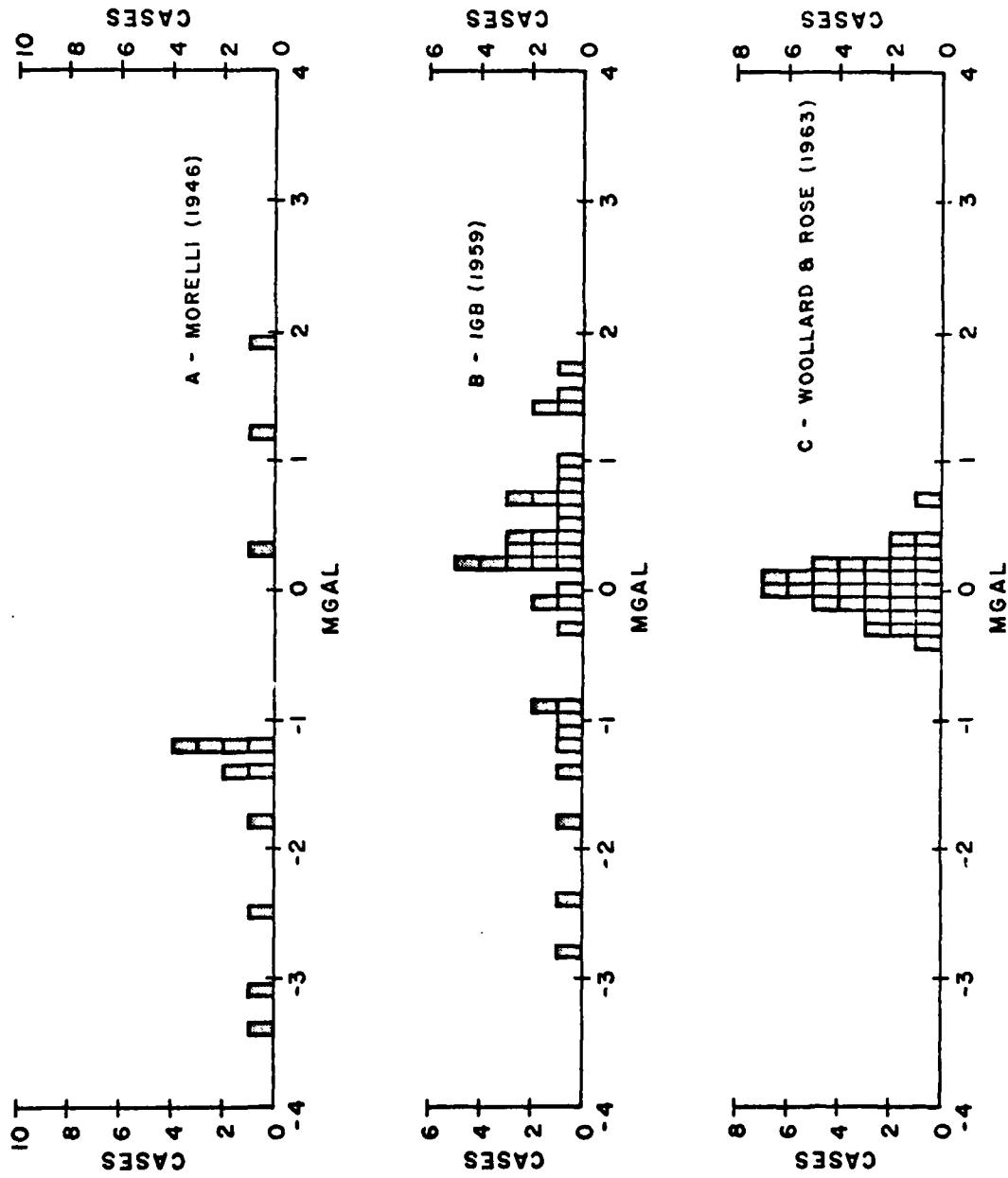


Fig. 2. Distribution plots of differences in datum standardized values of Morelli (1946), the IGB (1959) and Woollard and Rose (1963) and IGSN 71 values at the world fundamental gravity bases.

The Woollard and Rose (1963) datum corrected values (Figure 2-C) in contrast to the Morelli (1946) and IGB values define a near Gaussian distribution centered at + 0.05 mgal, indicating that the median value departs by - 14.65 mgal from the IGSN 71 datum rather than the -14.7 mgal datum difference defined by the IGSN 71 value for the Madison, Wisconsin base. As this degree of skewness in the data has no statistical significance it can be ignored.

In order to examine the gravity standards defined by the above groups of values relative to that incorporated in the IGSN 71 values, the datum corrected differences in values are plotted as a function of absolute gravity in Figure 3. Figure 3-A shows the values of Morelli (1946) and Hirvonen (1948). Both sets of values define essentially the same pattern of difference relative to the IGSN 71 values: two groupings of values which are separated by about 2.9 mgal. Both sets of values also indicate much the same departure in gravity standard: about 0.66 mgal per 1000 mgal change relative to the standard represented in the IGSN 71 values. The datum corrected IGB values for the world fundamental gravity base sites (Figure 3-B) indicate only a slight difference in standard of about 0.2 mgal per 1000 mgal change from that of the IGSN 71 values. The Woollard and Rose (1963) values (Figure 3-C) define no discernible difference in gravity standard from that incorporated in the IGSN 71 values.

The various comparisons given in Table 1 and graphically portrayed in Figures 2 and 3, therefore, indicate that whereas

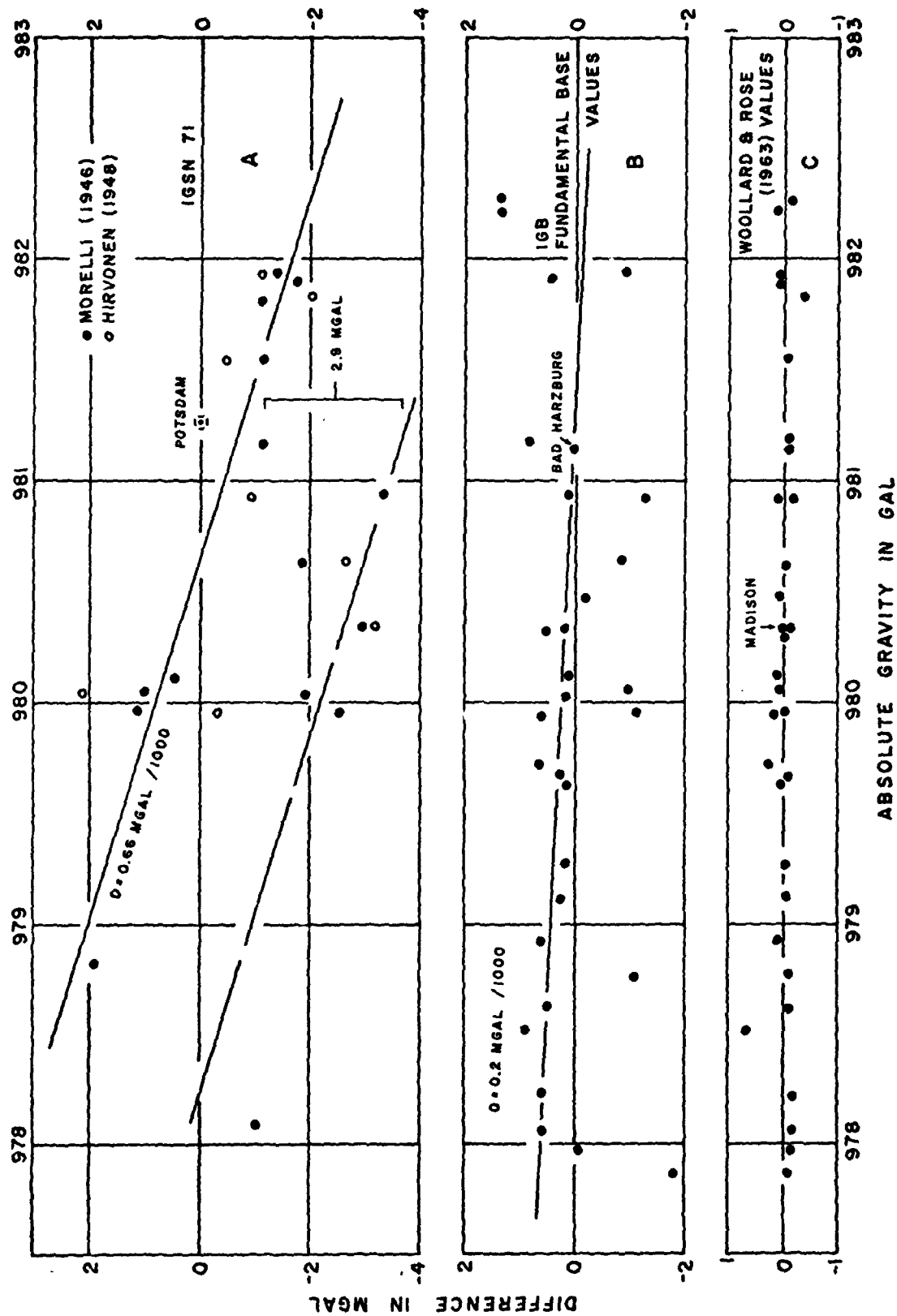


Fig. 3. Differences in gravity standard defined by the datum adjusted value of Morelli (1946), Hirvonen (1948), the IGB (1959) and Woollard and Rose (1963) relative to the IGSN 71 values at the world fundamental gravity bases.

there was a significant improvement in gravity standardization at key gravity bases throughout the world between 1948 and 1959, the most significant improvement was that represented in the Woollard and Rose (1963) values. Subsequent improvement as represented in the IGSN 71 values has been primarily in terms of a revision of the absolute gravity datum values that had been in use, and a reduction in the uncertainty in relative gravity values from about  $\pm 0.15$  mgal on average as represented in the Woollard and Rose values to about  $\pm 0.05$  mgal on average as represented in the IGSN 71 values. As indicated earlier there is no apparent difference in gravity standard represented in the Woollard and Rose (1963) values and the IGSN 71 values of Morelli et al (1974).

INHERENT LIMITATIONS IN THE WOOLLARD AND ROSE (1963) VALUES  
RELATED TO INSTRUMENT CALIBRATION

Woollard and Rose (1963) used modified sets of minimum compound quartz pendulum apparatus built by the Gulf Oil Company Research and Development Corporation to make gravity observations which were used as a standard in establishing the overall calibration of the gravimeters they used. The primary series of such pendulum observations in North America included ten sites, other than the Madison, Wisconsin base, distributed between Point Barrow, Alaska and Mexico City, Mexico. Adjunct pendulum measurements were also made along the Pacific coast at Vancouver, Seattle and San Francisco; in the mid-continent region at Madison, Huron, Chicago, Beloit, Tulsa and Houston; and along the Atlantic coast from

Ottawa to Key West. The relative change in gravity along these lines of pendulum measurements which covered over 4700 mgal on the Pt. Barrow to Mexico City series when considered in combination with the laboratory determined calibration of gravimeters provided the gravity standard for most of the Woollard and Rose (1963) gravimeter results.

The limiting factor on the reliability of the calibration of the Woollard and Rose gravimeter data, however, was not in the overall calibration standard defined by the pendulum measurements, but rather pseudo cyclic short to medium range deviations in the readings of the gravimeters. A similar cyclic problem (screw effect) had been early recognized in the use of the Worden gravimeters since reading idiosyncracies could be detected with that instrument's two dial reading system. However, such problems were not recognized as being associated with the LaCoste and Romberg gravimeters until after the publication of the Woollard and Rose (1963) results. What brought this problem into focus was the use of two LaCoste and Romberg geodetic gravimeters simultaneously in 1963 in establishing pendulum site excenter base connections. Repeat measurements with both instruments indicated consistent differences of 0.1 to 0.5 mgal over gravity intervals of the order of 5 to 30 mgal, but with agreement to 0.1 mgal or better over changes of the order of 500 mgal to 3000 mgal. These findings resulted in a series of tests (Woollard, 1964) to establish the cause of the discrepancies, and the source was found to be related to apparent non-periodic deviations in instrument res-



ponse which had not been detected in the initial laboratory calibration of the gravimeters. As these discrepancies in instrument readings set one of the limits on the reliability of the Woollard and Rose (1963) values, the results of a 32-point laboratory test calibration versus that defined originally using an 11-point laboratory calibration for LaCoste and Romberg geodetic gravimeter LRG-1, which was used in standardizing most of the Woollard and Rose (1963) values, are shown in Figure 4 along with the calibration defined by the pendulum observations. The bottom curve (open point values) represents the original laboratory calibration based on 11 points; this curve parallels closely the top curve (x point values) representing the calibration based on the pendulum observations. Superimposed and lying between these two curves are shown the results (solid point values) obtained for the 32-point laboratory calibration. As seen, there is a non-systematic oscillation in values about a mean curve whose position departs in a near-linear fashion from that of the original calibration and that defined by the pendulum measurements. The effect of these anomalous deviations in the calibration of LRG-1 on the Woollard and Rose (1963) values at the pendulum sites and their excenters between Point Barrow and Mexico City is brought out in Figure 5. In this figure the IGSN 71 values of Morelli et al (1974) are used as a standard for comparison. In order to show also the effect of improvements in gravimeter instrumentation and calibration following the construction of the first LaCoste and Romberg geodetic gravimeter,

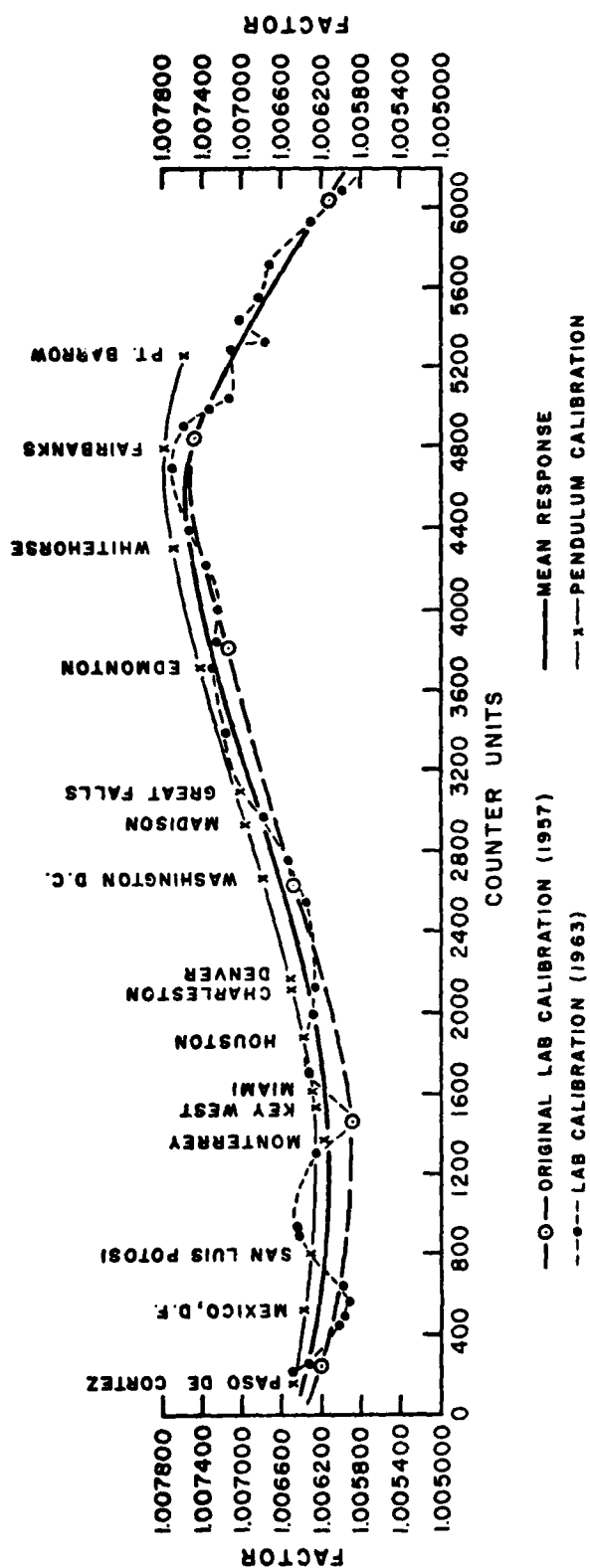


Fig. 4. Comparison of differences in calibration scale factor for gravimeter LRG-1 as defined by an 11-point laboratory calibration (1957), a 32-point laboratory calibration (1963) and pendulum observations Point Barrow, Alaska to Paso de Cortes, Mexico.

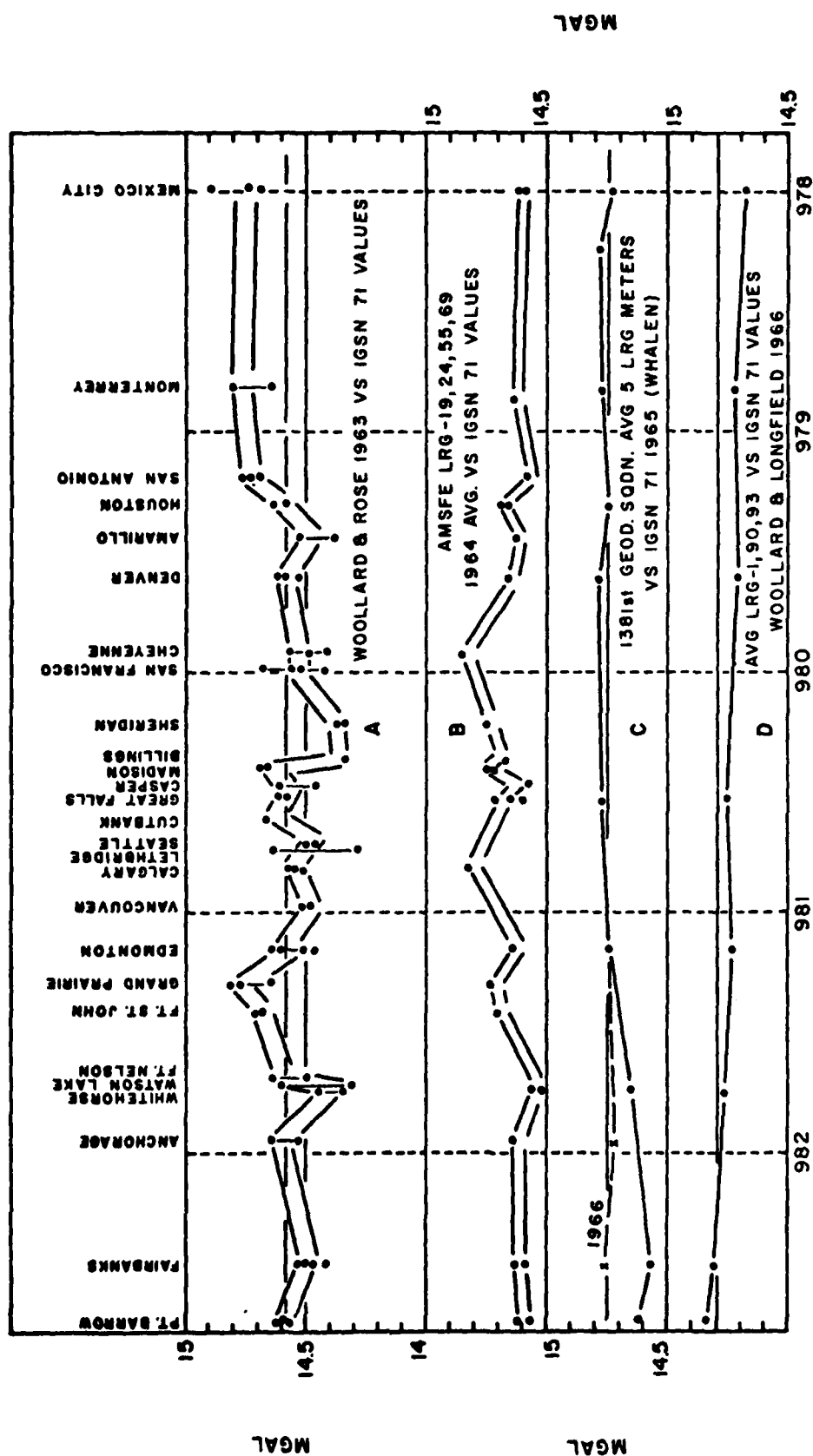


Fig. 5. Comparison plots using the IGSN 71 values of Morelli et al. (1974) as a standard in depicting improvements in gravimeter results obtained with LaCoste and Romberg geodetic gravimeters at the same sites on the North American Rocky Mt. front gravity standardization range over the period 1957-1966.

Figure 5 includes three additional sets of results obtained with LaCoste and Romberg geodetic gravimeters at the same sites at different periods in time. Figure 5-A presents the difference in the Woollard and Rose (1963) values at the pendulum sites and their excenters relative to the IGSN 71 values between Pt. Barrow and Mexico City plotted as a function of absolute gravity. Values at certain off-line pendulum sites (Anchorage, Vancouver, Seattle, Madison, San Francisco and Houston) are also included to give a more complete representation comparable to the changes brought out in Figure 4. A best overall fit to the values would define no overall systematic difference in gravity standard from that incorporated in the IGSN 71 values, and would indicate a datum correction of about -14.57 mgal. However, there is an average of about 0.1 mgal (and occasionally even greater) discrepancy in the pendulum base ties to their excenters, and as is seen, pseudo cyclic deviations in values of the order of  $\pm 0.2$  mgal from the mean.

The improvement in the next generation of gravimeters built by LaCoste and Romberg is brought out in Figure 5-B, which presents the average results (unpublished) obtained by the then Army Map Service, Far East in 1964 over the North American Gravity standardization range using four LaCoste Romberg gravimeters. The spread in pendulum base to excenter values at any one site relative to the IGSN 71 values in this plot is, in general, only about 0.05 mgal, and although the short period pseudo cyclic deviations have been reduced to about  $\pm 0.15$  mgal, there is a

long period deviation of about  $+0.2$  mgal from the IGSN 71 values in the mid-range section.

In Figure 5-C, the average values obtained with five LaCoste gravimeters by the Air Force 1281st Geodetic Squadron (Whalen, unpublished) at most of the same sites in 1965 are shown relative to the IGSN 71 values. These values indicate that the pseudo cyclic deviations in values had been reduced by this time to the point that the uncertainty in values was no more than about  $0.04$  mgal. Except for the sector north of Edmonton, Canada, no long wave length deviation in values is indicated. That this defect was removed by a subsequent more complete laboratory calibration is indicated by the 1966 values reported by Whalen (unpublished) for Anchorage and Fairbanks.

Figure 5-D shows the values obtained by Woollard and Longfield in 1966 (unpublished) using two later generation LaCoste and Romberg gravimeters and with LRG-1 recalibrated using the 32-point laboratory calibration shown in Figure 4. As is evident, this set of values indicate a difference of about  $0.025$  mgal per 1000 mgal change in gravity standard from that incorporated in the IGSN 71 values. Since the calibration standard for the set of gravimeter values shown in Figure 5-D was defined by more precise pendulum observations (Woollard and Longfield, unpublished) than were available when the Woollard and Rose (1963) values were published as well as by multiple point laboratory calibrations for each gravimeter, these results raise a question regarding the gravity standard represented in the IGSN 71 values. It appears

significant that the difference in gravity standard depicted is much the same and in the same sign as the difference the writer (Woollard, this volume) finds in the agreement of the IGSN 71 values of Morelli et al (1974) with the 10 absolute gravity determinations used in the IGSN 71 adjustments. However, the small discrepancy suggested in the IGSN 71 gravity standard can be disregarded because it has no significance in evaluating the Woollard and Rose (1963) values since both sets of values appear to be on the same standard as brought out in Figures 3-C and 4-A.

With the above points established concerning the Woollard and Rose (1963) values in general at gravity standardization sites in North America, the data pertaining to each of the four North-South series of pendulum bases established in North America will be considered separately, since it is on an individual basis that the range data have been utilized.

COMPARISONS OF WOOLLARD AND ROSE (1963) AND IGSN 71 VALUES ON THE NORTH AMERICAN GRAVITY STANDARDIZATION RANGES.

As in Figure 5, the differences in the Woollard and Rose (1963) gravimeter values relative to the IGSN 71 values of Morelli et al (1974) are examined over the range in absolute gravity represented on each gravity range. The center point values on the plots shown in Figure 6 represent the average departure of the Woollard and Rose (1963) values from the IGSN 71 values at each site (pendulum base and its excenters), and the spread in the values is indicated by the error bar. Because there is an apparent offset (tare) in the Woollard and Rose values at and south of

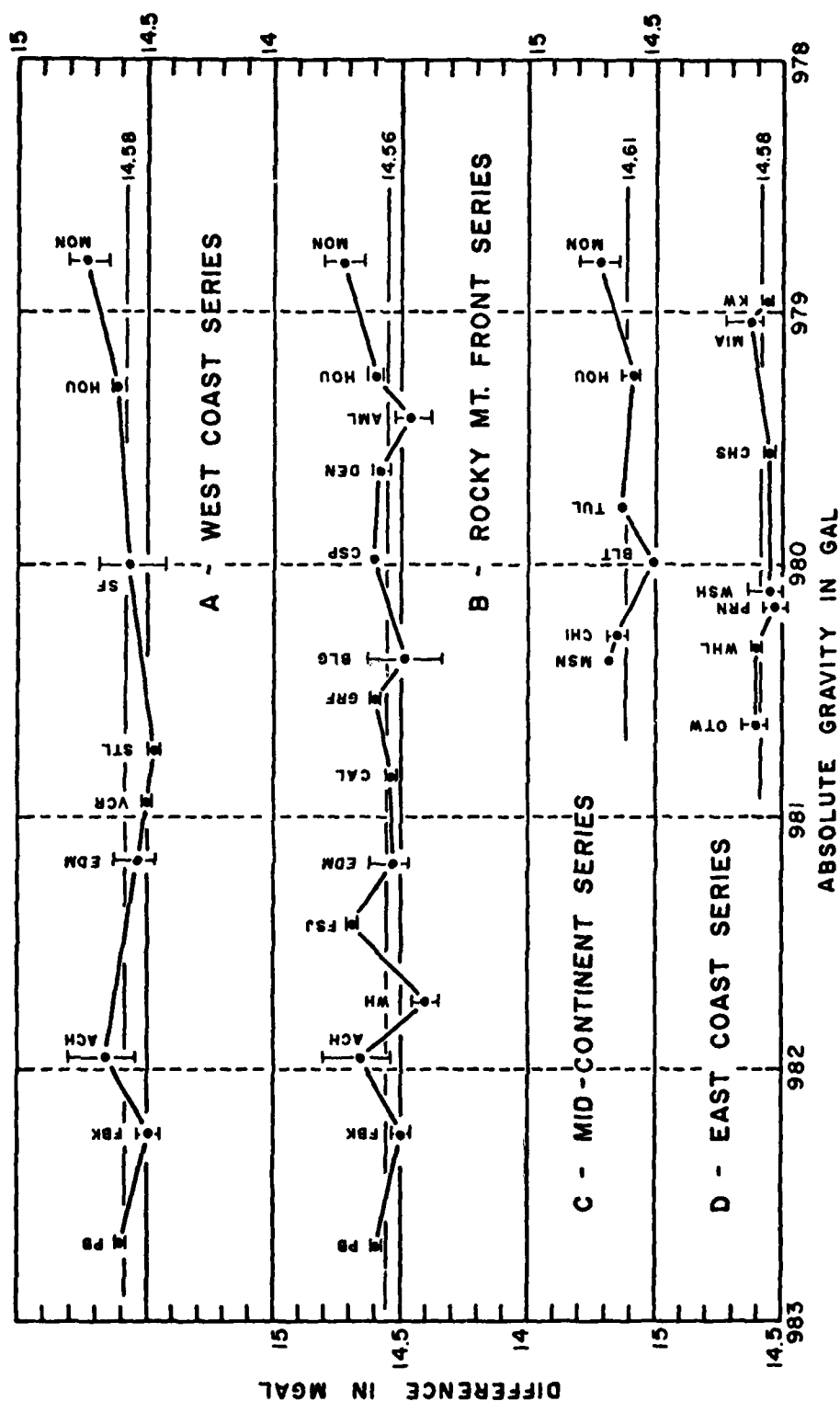


Fig. 6. Comparison of Woollard and Rose (1963) gravimeter values and IGSN 71 values at pendulum sites on each of the North American gravity standardization ranges. A - West Coast Range: PB - Point Barrow; FBK - Fairbanks; ACH - Anchorage; EDM - Edmonton; VCR - Victoria; STL - Seattle; SF - San Francisco; HOU - Houston; MON - Monterrey. B - Rocky Mt. Range: PB, FBK, ACH, EDM, HOU and MON as on A; WH - Whitehorse; FSJ - Fort St. John; CAL - Calgary; GRF - Great Falls; BLG - Billings; CSP - Casper; DEN - Denver; AML - Amarillo. C - Mid-Continent Range: MSN - Madison; CHI - Chicago; BLT - Beloit; TUL - Tulsa; HOU and MON as in A. D - East Coast Range: OTW - Ottawa; WHL - Woods Hole; PRN - Princeton; WSH - Washington; CHS - Charleston; MIA - Miami; KW - Key West.

Mexico City, Monterrey, Mexico is taken as the terminus for each series of observations except the Atlantic coast series that ends at Key West, Florida.

From a casual inspection of the four plots shown in Figure 6, it is clear that there are no overall differences in gravity standard from that defined by the IGSN 71 values on any of the pendulum base lines and very little spread in the absolute datum offset. The datum differences range on average from +14.56 mgal for the Rocky Mt. series of bases to +14.61 mgal for the Mid-Continent series; the West Coast and East Coast series both show a datum offset of about +14.58 mgal. In general, departures of individual site values from the datum offset indicated for a series as a whole, do not exceed 0.1 mgal, and the last series established (the East Coast series) is clearly the best series of measurements.

These results therefore are in good agreement with those indicated at the IGB fundamental gravity base sites as regards agreement in gravity standard with that incorporated in the IGSN 71 values. However, there is a difference as regards the datum offset, which is about 0.1 mgal less ( $\approx 14.6$  vs.  $14.7$  mgal) than that indicated by the comparisons at the IGB fundamental gravity bases.

#### COMPARISONS OF WOOLLARD AND ROSE (1963) AND IGSN 71 VALUES AT GRAVITY STANDARDIZATION BASES IN SOUTH AMERICA

In Figure 7 three plots similar to those of Figure 6 are shown for the differences in Woollard and Rose (1963) values and



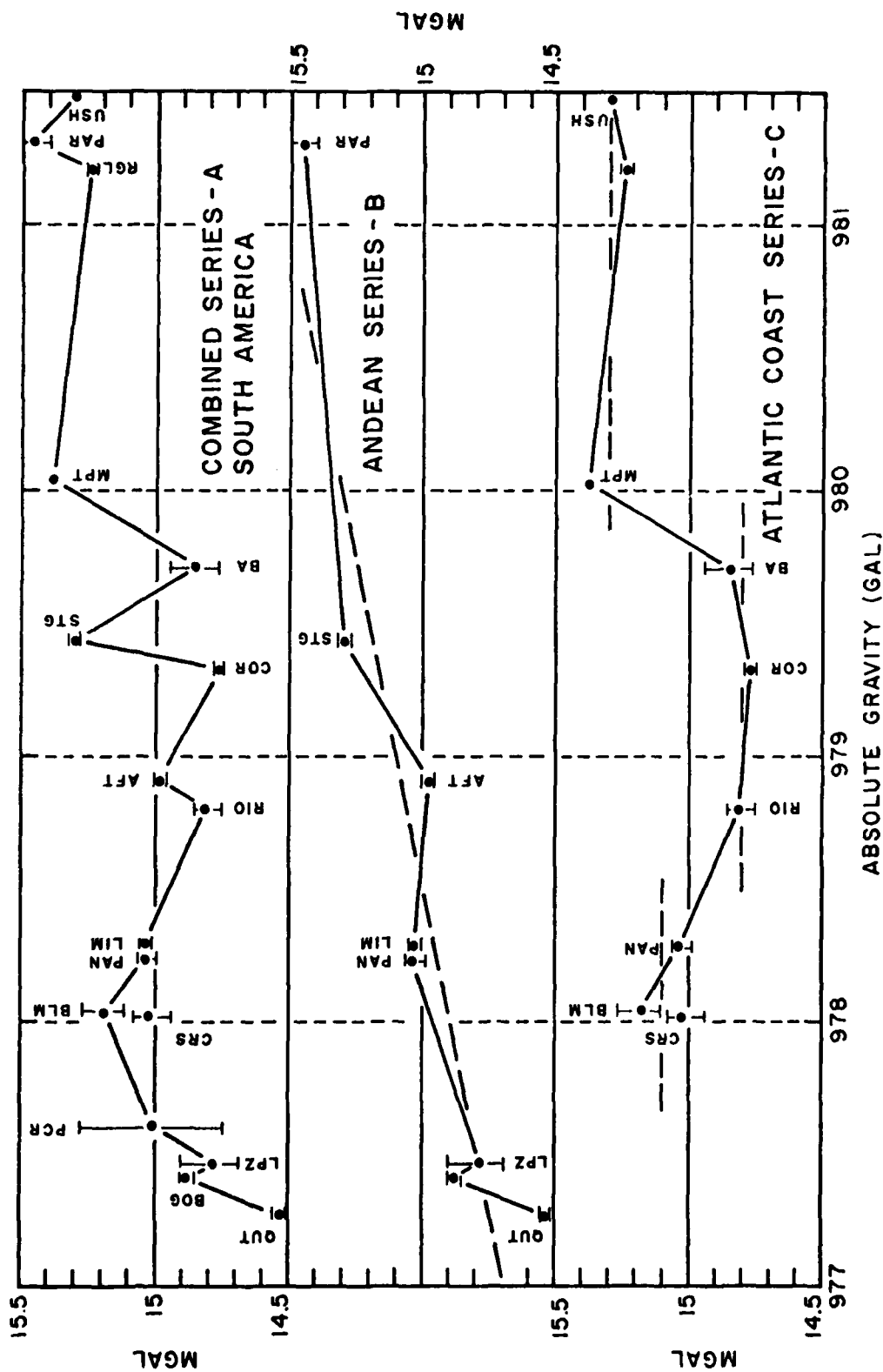


Fig. 7. Comparison of Woollard and Rose (1963) gravimeter values and IGSN values at pendulum sites in South America. A - Combined data for all sites: QUT - Quito; BOG - Bogota; LPZ - La Paz; PCR - Paso de Cortes (Mexico); CRS - Caracas; BLM - Belem; PAN - Panama; LIM - Lima; RIO - Rio de Janeiro; AFT - Antofagasta; COR - Cordoba; STG - Santiago; BA - Buenos Aires; MPT - Mar del Plata; RGL - Rio Gallegos; PAR - Punta Arenas; USH - Ushuaia. B - Andean Series: Panama to Punta Arenas, Chile. C - East Coast Series: Panama to Ushuaia, Argentina.

the IGSN 71 values of Morelli et al (1974) at pendulum bases in South America. In order to preserve North and South geographic continuity with Figure 6, however, the absolute gravity scale is reversed and the values increase from left to right. In Figure 7-A all of the data are combined into a single plot with an overlap of values from Paso de Cortes, Mexico southward. This plot suggests both a difference in gravity standard from that of the IGSN 71 values and much larger site-to-site departures from some mean value than was brought out by the data for North America.

To resolve the sources of the discrepancies, the data are divided into two groups corresponding to the East-West distribution pattern of the observation sites. Figure 7-B presents the differences for the Andean series of sites from Panama southward to Punta Arenas, Chile, and Figure 7-C for the eastern series of sites from Caracas, Venezuela to Ushuaia, Argentina. As is evident from Figure 7-B, the Andean series of observations is largely responsible for the departure from the IGSN 71 gravity standard suggested in Figure 7-A, and the departure indicated is about +0.2 mgal per 1000 mgal increase in gravity values. In other respects the differences in values are similar to those noted in North America.

In the case of the eastern series (Figure 7-C) it appears that two major tares are involved. One, of about -0.3 mgal, is indicated between Belem and Rio de Janeiro; another, in opposite sign and of about +0.5 mgal, is indicated between Buenos Aires and Mar del Plata. On this interpretation of differences of the

Woollard and Rose values from the IGSN 71 values in eastern South America, no difference in gravity standard is indicated from that of the IGSN 71 values. As it is not likely that two such dissimilar patterns of differences in the Woollard and Rose (1963) values from the IGSN 71 values at the pendulum base sites could have developed in South America, these results will be considered further in examining the data for all sites in South America on an areal basis.

COMPARISONS OF WOOLLARD AND ROSE (1963) VALUES AND IGSN 71 VALUES AT GRAVITY STANDARDIZATION BASES IN EUROPE

Figure 8 shows plots of differences in Woollard and Rose (1963) values and IGSN 71 values at gravity standardization bases in Europe. Figure 8-A is a plot of the differences as a function of the change in absolute gravity from Hammerfest, Norway to Madrid, Spain with an overlap of values into northern Africa. The mean difference in values is about 14.75 mgal, and although there is a scatter of about  $\pm 0.2$  mgal about the mean, no obvious difference in gravity standard is indicated on an overall basis from that incorporated in the IGSN 71 values. However, there is a suggestion in two sectors (Hammerfest to Helsinki and Paris to Madrid) of a relation similar to that noted in South America for the Andean series of observations. If the distribution of the differences are examined on an individual basis (base sites and excenters as separate observations) as shown in Figure 8-B, a bimodal distribution is indicated. The predominant values occur at 14.7 and 14.9 mgal. These values are substantiated by the distri-

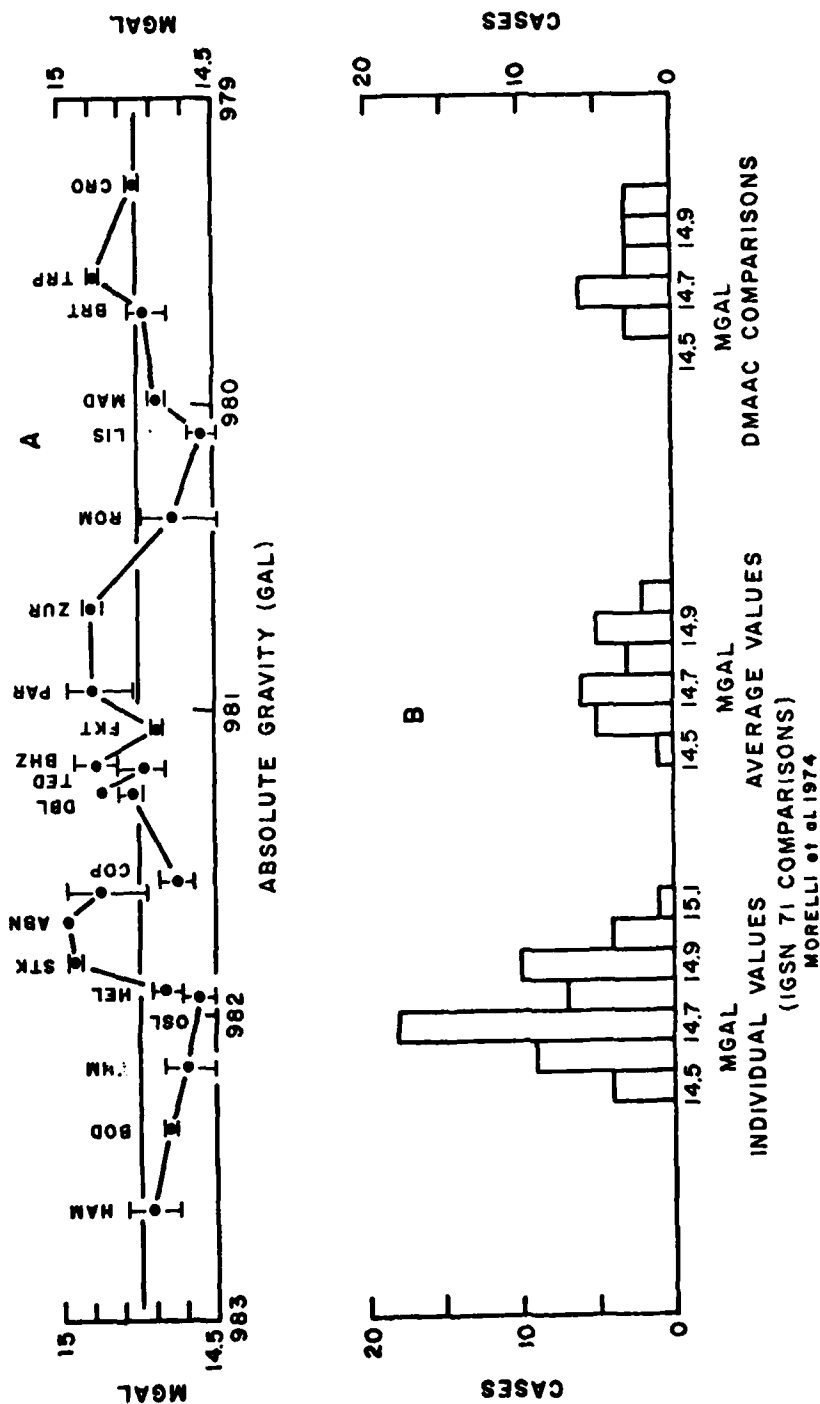


Fig. 8. Comparison of Woollard and Rose (1963) and IGSN 71 values at gravity standardization bases in Europe. A - The differences as a function of absolute gravity. HAM - Hammerfest; BOD - Bodo; THM - Trondheim; OSL - Oslo; HEL - Helsinki; STK - Stockholm; ABN - Aberdeen; COP - Copenhagen; DBL - DeBilt; TED - Teddington; BHZ - Bad Harzburg; FKT - Frankfurt; PAR - Paris; ZUR - Zurich; ROM - Rome; LIS - Lisbon; MAD - Madrid; BRT - Beirut; TRP - Tripoli; CRO - Cairo. B - Distribution plots of the differences in values.

bution plot for the averaged values for each base. Because attention was called to the difference in IGSN 71 values as derived by Morelli et al (1974) and DMAAC (unpublished), a plot of differences relative to the DMAAC IGSN 71 values at the pendulum bases is also shown. This plot indicates a skewed distribution with a predominant value of 14.7 mgal. All of the distribution plots thus suggest that there are tares of the order of 0.2 mgal in the European values, but it is not clear whether there is any difference in gravity standard.

COMPARISON OF WOOLLARD AND ROSE (1963) AND IGSN 71 VALUES AT GRAVITY STANDARDIZATION BASES IN AFRICA

In Figure 9 plots of the differences in Woollard and Rose (1963) values and IGSN 71 values at gravity standardization bases in Africa are shown as a function of absolute gravity values. As the minimum gravity value occurs in the mid-continent region near the Equator, 977.5 gal is adopted as a center point of minimum absolute gravity with values increasing in both directions from it in order to have north-south geographic integrity. Figure 9-A is a plot of the differences in values at all base sites in Africa with an overlap of sites into southern Europe. Although there is good continuity with the average relations brought out in Figure 9-A for Europe, there appears to be a major tare separating the data for the northern half of the continent from that for the southern half. The values for sites in the southern sector, also appear to be influenced by a significant difference in gravity standard. That this difference in

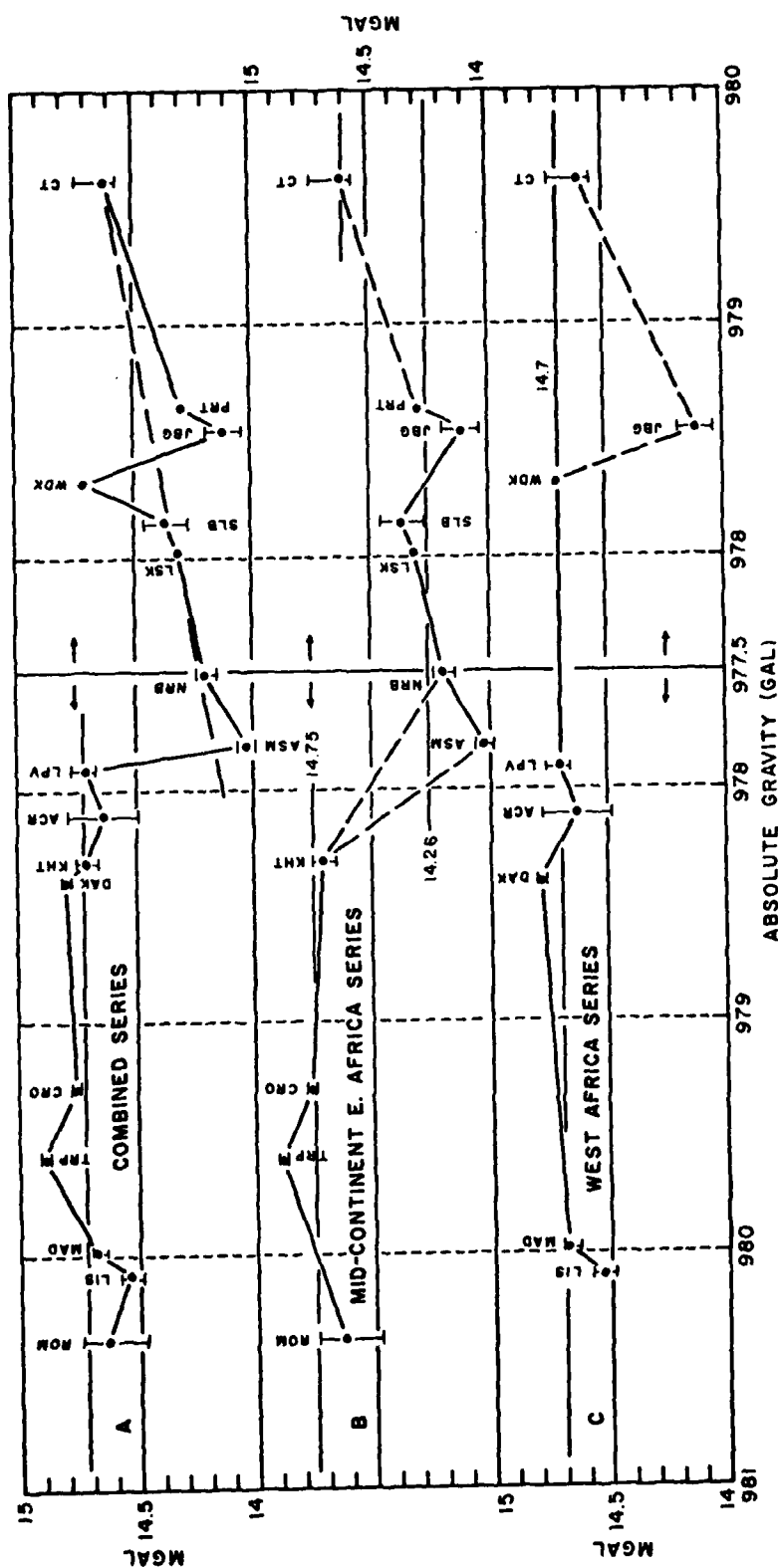


Fig. 9. Comparison of Woollard and Rose (1963) and IGSN 71 values at gravity standardization bases in Africa. A - Combined data for all sites in Africa. ROM - Rome; LIS - Lisbon; MAD - Madrid; TRP - Tripoli; CRO - Cairo; DAK - Dakar; KHT - Khartoum; ACR - Acra; LPV - Leopoldville; ASM - Asmara; NRB - Nairobi; LSK - Lusaka; SLB - Salisburg; WDK - Windhoek; JBG - Johannesburg; PRT - Pretoria; CT - Capetown. B - Mid-Continent-East Africa Series: Rome, Italy to Capetown, South Africa via Nairobi, Kenya. C - West Africa Series: Madrid, Spain to Capetown, South Africa via Leopoldville (Kinshasa), Zaire.

pattern is a consequence of tares rather than any difference in gravity standard is brought out in Figure 9-B and 9-C, in which the data are subdivided to conform to the East-West geographic distribution of the observation sites. Figure 9-B is for the mid-continent East Africa area, and Figure 9-C is for the West Africa area with an overlap of sites at Johannesburg and Capetown. As seen from Figure 9-B, the mean datum difference relative to the IGSN 71 values is 14.75 mgal from Rome to Khartoum with a tare of about -0.5 mgal between Khartoum and Nairobi and a compensating tare of about +0.4 mgal between Johannesburg and Capetown. That the apparent slope suggested by the data for sites between Asmara and Capetown is fortuitous and a consequence of tares is supported by the data of Figure 9-C. In this plot only the Johannesburg value is seen to be anomalous. All of the other site values show no difference in gravity standard from that of the IGSN 71 values and the datum offset of 14.7 mgal agrees with that for Europe and the northern segment of the East African measurements.

#### COMPARISONS OF WOOLLARD AND ROSE (1963) AND IGSN 71 VALUES AT GRAVITY STANDARDIZATION BASES IN THE PACIFIC SECTOR

Because all gravity ties to the Asia-Australia sector were made from San Francisco via Hawaii, the base value comparisons with IGSN 71 values for these two sites are considered as a part of the group of values for Japan, Southeast Asia, Australia and New Zealand. Figure 10-A shows the differences in Woollard and Rose values relative to the IGSN 71 values plotted as a function

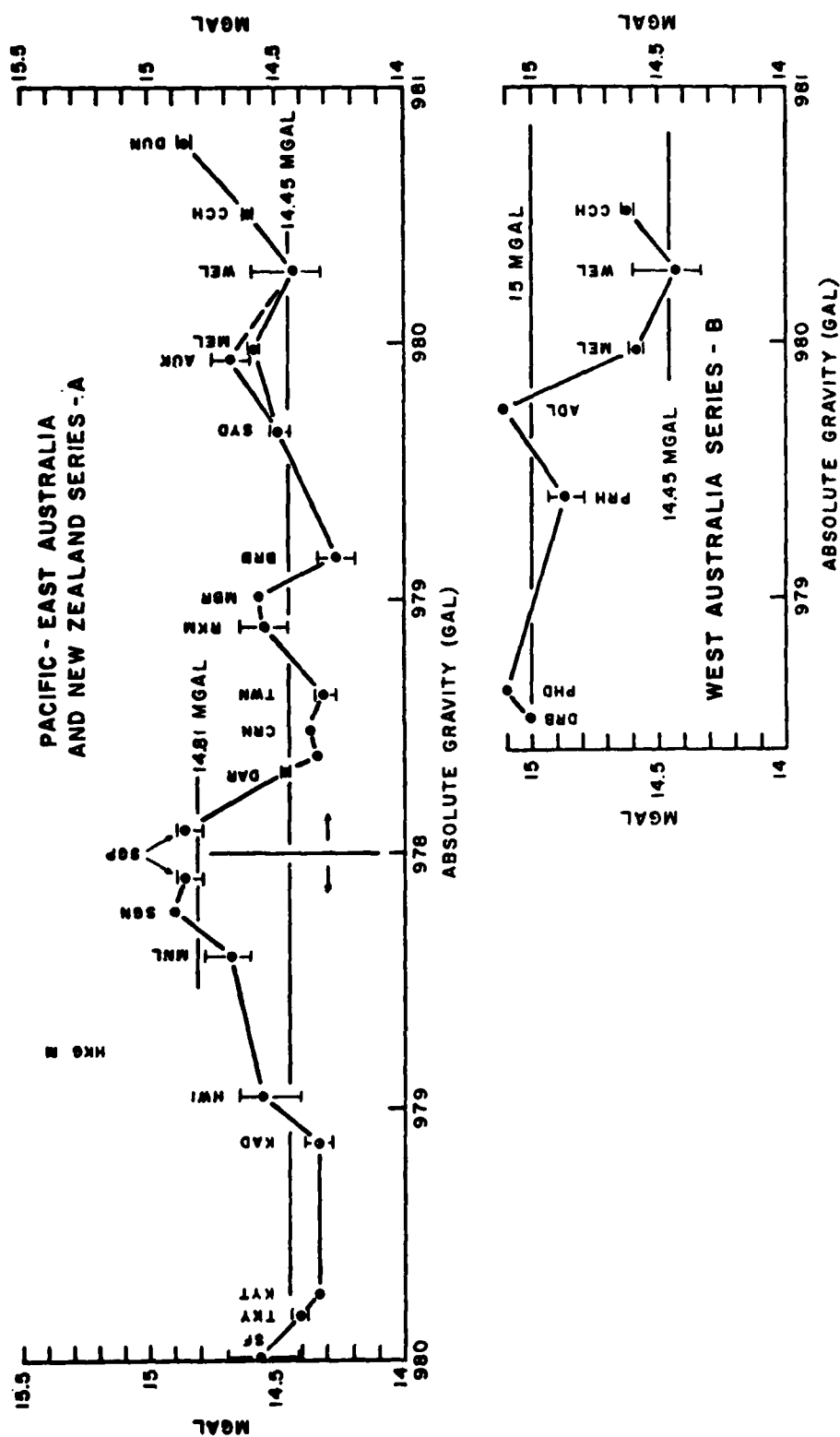


Fig. 10. Comparison of Woollard and Rose (1963) and IGSN 71 values at gravity standardization bases in the Pacific sector. A - Main Series: Japan to New Zealand. SF - San Francisco; TKY - Tokyo; KYT - Kyoto; KAD - Kadena (Okinawa); HWI - Hawaii; HKG - Hong Kong; MNL - Manila; SGN - Saigon; SGP - Singapore; DAR - Darwin; CRN - Cairns; TWN - Townsville; RKM - Rockhampton; MBR - Maryborough; BRB - Brisbane; SYD - Sydney; AUK - Auckland; MEL - Melbourne; WEL - Wellington; CCH - Christchurch; DUN - Dunedin. B - Western Australia Series: DRB - Derby; PHD - Port Hedland; PHR - Perth; ADL - Adelaide; MEL, WEL, and CCH as in A.



of absolute gravity for all sites in the above areas except those in western Australia, which are considered separately since they appear to be affected by a tare. As in the case of Africa, a minimum absolute gravity value (980.00 gal) is taken as a center point in considering sites north and south of Singapore. In Figure 10-A, except for the values at Hong Kong, which appear to be poor measurements; Dunedin, New Zealand, which appears to be affected by a tare; and Manila, Saigon and Singapore, which all appear to be definitely affected by a tare of about 0.36 mgal, all values indicate a datum offset of about 14.45 mgal from the IGSN 71 values with no indication in gravity standard. As shown in Figure 10-B there is an indication of a tare of about +0.53 mgal between Melbourne and Adelaide in proceeding from eastern to western Australia, which increases the difference to about 15.0 mgal for these sites relative to the IGSN 71 values.

#### SUMMARY ON WOOLLARD AND ROSE VALUES VERSUS IGSN VALUES AT GRAVITY STANDARDIZATION BASES

Except for the series of Woollard and Rose gravimeter values, from Panama to Punta Arenas, Chile, none of the series of measurements on the gravity standardization ranges appear to be on a different gravity standard from that incorporated in the IGSN 71 values. There are, however, apparent tares ranging from 0.2 mgal to 0.5 mgal that result in datum offsets in some of the series of measurements; notably, the east coast series in South America, the mid-continent East Africa series, and the Pacific series. There are also a few sites that appear to be in significant

error, such as Asmara, Ethiopia and Hong Kong.

As the absolute gravity value (980.3689 gal) used by Woollard and Rose for their primary reference base at Madison, Wisconsin is 14.7 mgal high relative to the IGSN 71 value for Madison, (980.3542 gal), all of the Woollard and Rose values should differ approximately this amount from their corresponding IGSN 71 values. The actual mean differences noted by geographic area and percentage of values in each series showing agreement to  $\pm 0.1$  mgal and  $\pm 0.2$  mgal or better with the mean for each series are as follows:

World net of IGB fundamental bases: 32 sites

Mean datum difference: +14.7 mgal

Percentage showing agreement to  $\pm 0.1$  mgal: 58%

Percentage showing agreement to  $\pm 0.2$  mgal: 82%

North American gravity standardization bases: 40 sites

Mean datum difference: +14.6 mgal

Percentage showing agreement to  $\pm 0.1$  mgal: 83%

Percentage showing agreement to  $\pm 0.2$  mgal: 95%

Erratics: Paso de Cortes, Mexico +15 mgal

South American gravity standardization bases:

Eastern series: 12 sites, segmented by tares

(1) Panama, Caracas, Belem:  $15.1 \pm 0.1$  mgal

(2) Rio de Janeiro, Cordoba, Buenos Aires:  $14.8 \pm 0.05$  mgal

(3) Mar del Plata, Rio Gallegos, Ushuaia:  $15.3 \pm 0.05$  mgal

Andean series: 8 sites with different gravity  
standard

Panama to Punta Arenas, Chile

$X = 14.7 + 0.2$  (Woollard and Rose value -977.0)

Percentage showing agreement to  $\pm 0.1$  mgal: 75%

Percentage showing agreement to  $\pm 0.2$  mgal: 90%

European gravity standardization bases: 22 sites

Mean datum difference: 14.75 mgal

Percentage showing agreement to  $\pm 0.1$  mgal: 41%

Percentage showing agreement to  $\pm 0.2$  mgal: 86%

African gravity standardization bases

Western series: 8 sites, Lisbon and Madrid to  
Capetown

Mean datum difference: 14.7 mgal

Percentage showing agreement to  $\pm 0.1$  mgal: 75%

Percentage showing agreement to  $\pm 0.2$  mgal: 87%

Mid-continent-East African series: 1 sites  
segmented by tares

(1) Rome, Tripoli, Cairo, Khartoum, Capetown:  
14.75  $\pm 0.15$  mgal

(2) Nairobi, Lusaka, Salisbury, Johannesburg,  
Pretoria: 14.25  $\pm 0.15$  mgal

Erratics: Asmara: 14.05 mgal

Pacific gravity standardization bases: 24 sites

segmented by tares

(1) Principal series:

San Francisco, Hawaii, Tokyo, Kyoto, Darwin,  
Cairns, Townsville, Rockhampton, Maryborough  
Brisbane, Sydney, Melbourne, Auckland, Wellington  
and Christchurch:

Mean datum difference: 14.45 mgal

Percentage showing agreement to  $\pm 0.1$  mgal: 54%

Percentage showing agreement to  $\pm 0.2$  mgal: 94%

Erratics: Dunedin, New Zealand 14.85 mgal

(2) Manila, Saigon, Singapore:  $14.8 \pm 0.1$  mgal

Erratics: Hong Kong 15.4 mgal

Western Australia series:

Adelaide, Perth, Pt. Hedland, Derby:  $15.0 \pm 0.1$  mgal

#### COMPARISONS OF WOOLLARD AND ROSE (1963) VALUES AND IGSN 71 VALUES ON AN AREAL BASIS

As brought out earlier, a comprehensive worldwide comparison of Woollard and Rose values and IGSN 71 values is possible if the unpublished IGSN 71 values derived by the Defense Mapping Agency Aerospace Center are used to augment the values published by Morelli et al (1974). Although, as shown in Figure 1, the IGSN 71 values derived by DMAAC differ somewhat in datum and standard on an areal basis from those of Morelli et al (1974), the differences in general at any site do not exceed 0.04 mgal. This degree of difference in values is considered to be too small to constitute a significant limitation in using the DMAAC values to evaluate the Woollard and Rose (1963) values at airport and other sites for which there are not Morelli et al IGSN 71 values.

#### COMPARISON OF WOOLLARD AND ROSE (1963) AND IGSN 71 VALUES IN NORTH AMERICA

In order to take cognizance of the fact that a 13 year period is represented in the Woollard and Rose (1963) values;

that different instruments whose calibration was not always well established were used in different areas, and in some areas early measurements could not be repeated with improved instrumentation at other than the standardization bases, the data for North America are subdivided on an areal basis: Alaska, Canada, the United States, Mexico, and Central America and the West Indies. In Figure 11 distribution plots of the differences in the Woollard and Rose values and IGSN 71 values are shown for each of these areas. Figure 11-A presents the data for 58 sites in Alaska. Most of the differences in values (59%) fall within bounds of 14.4 to 14.8 mgal with a central tendency toward an average difference of about 14.55 mgal. In Figure 11-B the data for 57 sites in Canada are shown. In contrast to Alaska, a well-defined median value is indicated for the difference between the Woollard and Rose and IGSN 71 values. The value is 14.6 mgal and 76% of the values do not depart by more than 0.1 mgal from this mean. The data for the United States, which involves 163 sites, are shown in Figure 11-C. In this figure a slightly skewed distribution is indicated with a predominant mean difference value of 14.6 mgal. Agreement to within  $\pm 0.1$  mgal with this value is indicated for 64% of the values, and 82% of the values agree to within  $\pm 0.2$  mgal. The differences in values for the 29 sites in Mexico (Figure 11-D), are characterized by wide spread (13.4 to 15.5 mgal). There is no pronounced central tendency toward a dominant difference value, although 59% of the values fall within the bounds of 14.4 to 14.9 mgal. As the average difference in values for this central group

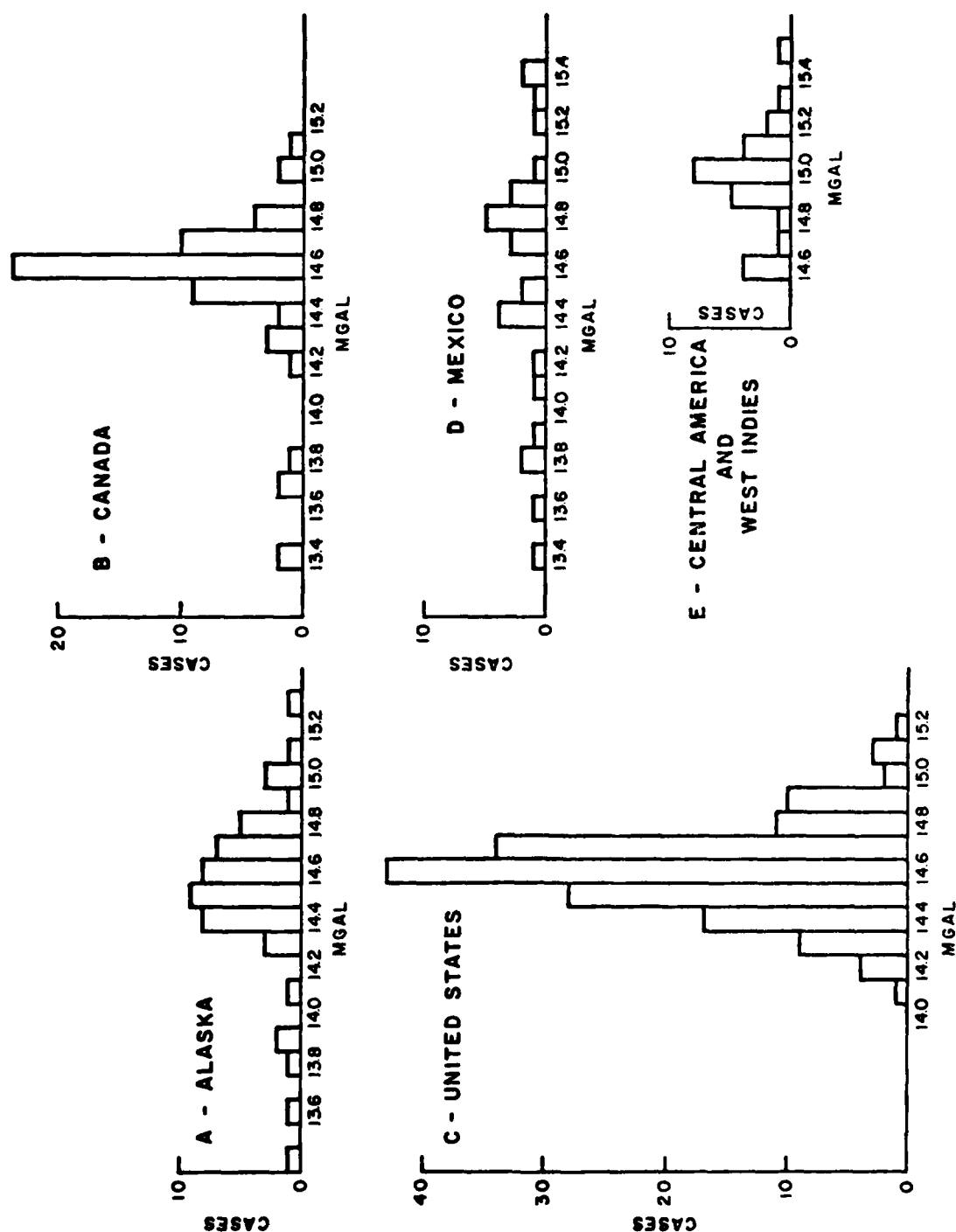


Fig. 11 Distribution of plots of differences in Woollard and Rose (1963) and IGSN 71 values in North America. A - Alaska. B - Canada. C - United States. D - Mexico. E - Central America and West Indies.

of values is 14.7 mgal, and is not significantly different from that indicated for Alaska, the United States and Canada. The comparisons for the 27 sites in Central America and the West Indies (Figure 11-E) indicate a mean difference of 15.0 mgal with 74% of the values differing by no more than 0.1 mgal from the mean. The significantly higher mean difference values for this group of data, 15.0 mgal versus 14.6 to 14.7 mgal elsewhere in North America, can be attributed to the fact that Panama was used as a base in establishing the values. As brought out when considering the gravity standardization base values, the Woollard and Pose value for Panama differs by 15.0 mgal from the IGSN 71 value.

If the above differences in Woollard and Pose and IGSN 71 values in North America are examined in terms of their relations to the change in absolute gravity represented (Figure 12), it is found that the patterns of differences for Alaska and Mexico differ significantly from those for the United States and Canada. In Alaska (Figure 12-A), and Mexico (Figure 12-B) apparent parallel alignments of values having much the same slope suggest that the gravity standard represented departs significantly from that of the IGSN 71 values and that several tares were involved in extending the network of airport base values from the primary bases (Fairbanks and Mexico City). The apparent explanations for the relations indicated in both areas are: (a) the work was done in the late 1940's and early 1950's prior to the development of the LaCoste and Romberg high range gravimeters and was done for the most part with Borden meters which, in addition to having a

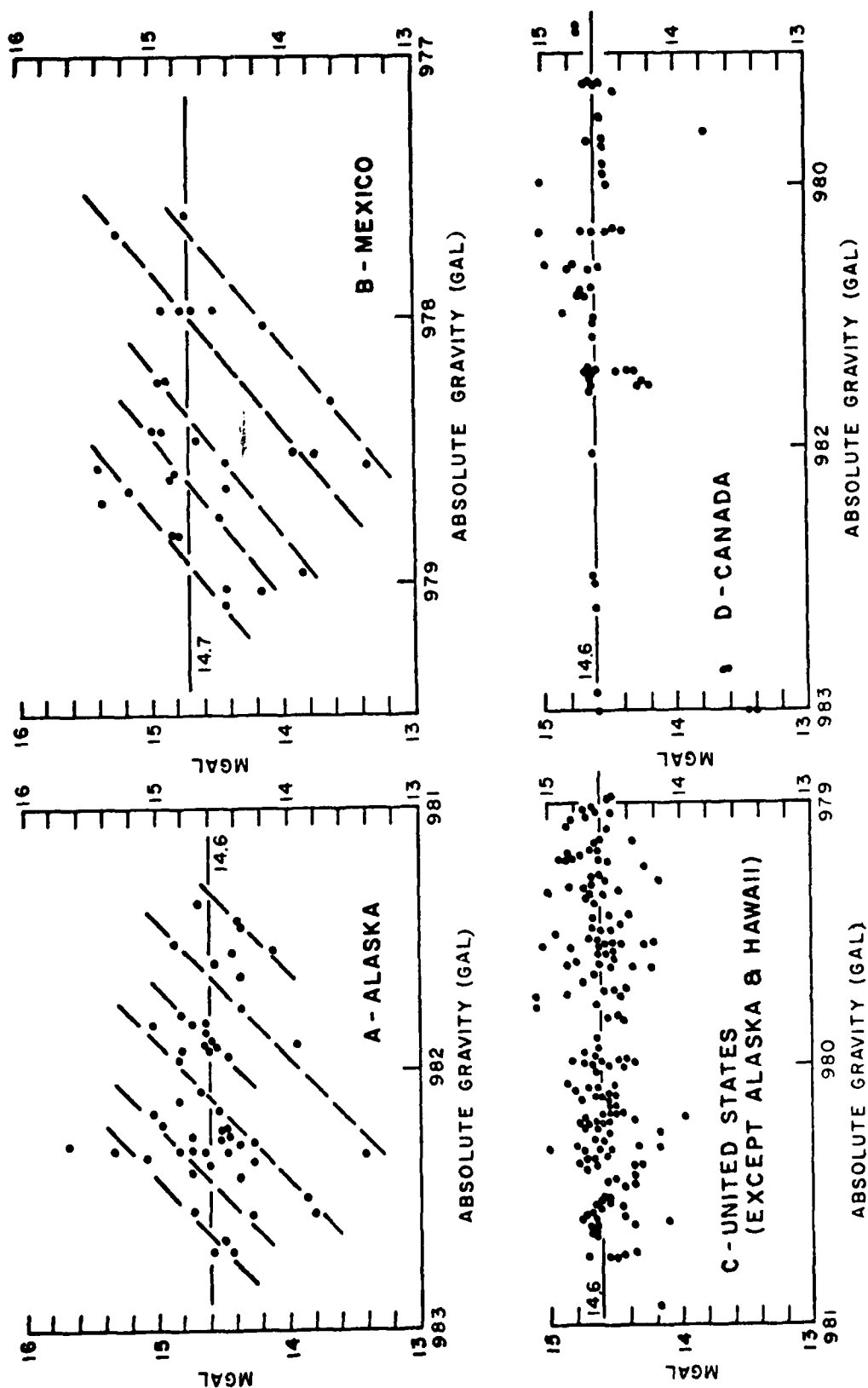


Fig. 12. Relations of differences in Woollard and Rose (1963) and IGSN 71 values in North America to change in absolute gravity. A - Alaska. B - Mexico. C - United States. D - Canada.



high drift rate that varied with type of transportation, were pressure (elevation) dependent and subject to tares from temperature shock as well as mechanical shock; (b) the measurements were made prior to the establishment of the North American pendulum gravity standardization range values and reflect limitations in making tilt table laboratory calibration at a mid-range site (in this case, Houston, Texas) covering the range of the instruments; (c) the measurements were made on a progressive loop basis using advance base sites from one closure loop as a base for the next closure loop, so that any error in a base value on one loop was propagated to the next loop; (d) it was possible to repeat only a few of the observations later with improved and better calibrated gravimeters. In view of the number of adverse factors represented in the data for Alaska and Mexico the pattern of departures in values found is not surprising.

In Figure 12-C the differences in the Woollard and Rose and IGSN 71 values in the United States are plotted as a function of absolute gravity. Although there is a suggestion that some of the problems indicated in Alaska and Mexico might have expression in some of the values, these represent exceptions. The better degree of agreement for these data in defining no difference in gravity standard from that incorporated in the IGSN 71 values can be attributed to the fact there were two or more sets of values for many sites and that many of the early values obtained with Worden gravimeters at airports (Woollard, 1958), were revised (Behrendt and Woollard, 1961) through repeat measurements using

the first LaCoste and Romberg geodetic gravimeter. However, these revisions were not drastic, for of the 39 reoccupations reported by Behrendt and Woollard (1961), 24 (61%) indicated agreement to 0.1 mgal or better, and 33 (85%) indicated agreement to 0.2 mgal or better with earlier Worden gravimeter values. The mean degree of agreement of the Woollard and Rose values with the IGSN 71 values is 14.6 mgal with 82% of the 163 values not departing by more than 0.2 mgal from the mean.

The data for Canada (Figure 12-D), except for five erratics, define a pattern similar to that in the United States. No difference in gravity standard is indicated from that defined by the IGSN 71 values and the mean departure in datum is 14.6 mgal. All the erratics but one appear to be related to a tare caused when the observer was caught in the backwash of a plane and sent tumbling (along with the gravimeter) across the ice in the Canadian Arctic. The IGSN 71 comparative values indicate the tare correction applied in reducing the data was incomplete for these sites.

#### COMPARISONS OF WOOLLARD AND ROSE (1963) AND IGSN 71 GRAVITY VALUES IN SOUTH AMERICA

Because of the difference in gravity standard brought out in the comparison of Woollard and Rose values at the gravity standardization bases in the Andean region of South America and the tares indicated in the eastern series of measurements, the differences at airport and port sites are considered on a country by country basis. Figure 13-A is the distribution plot of the

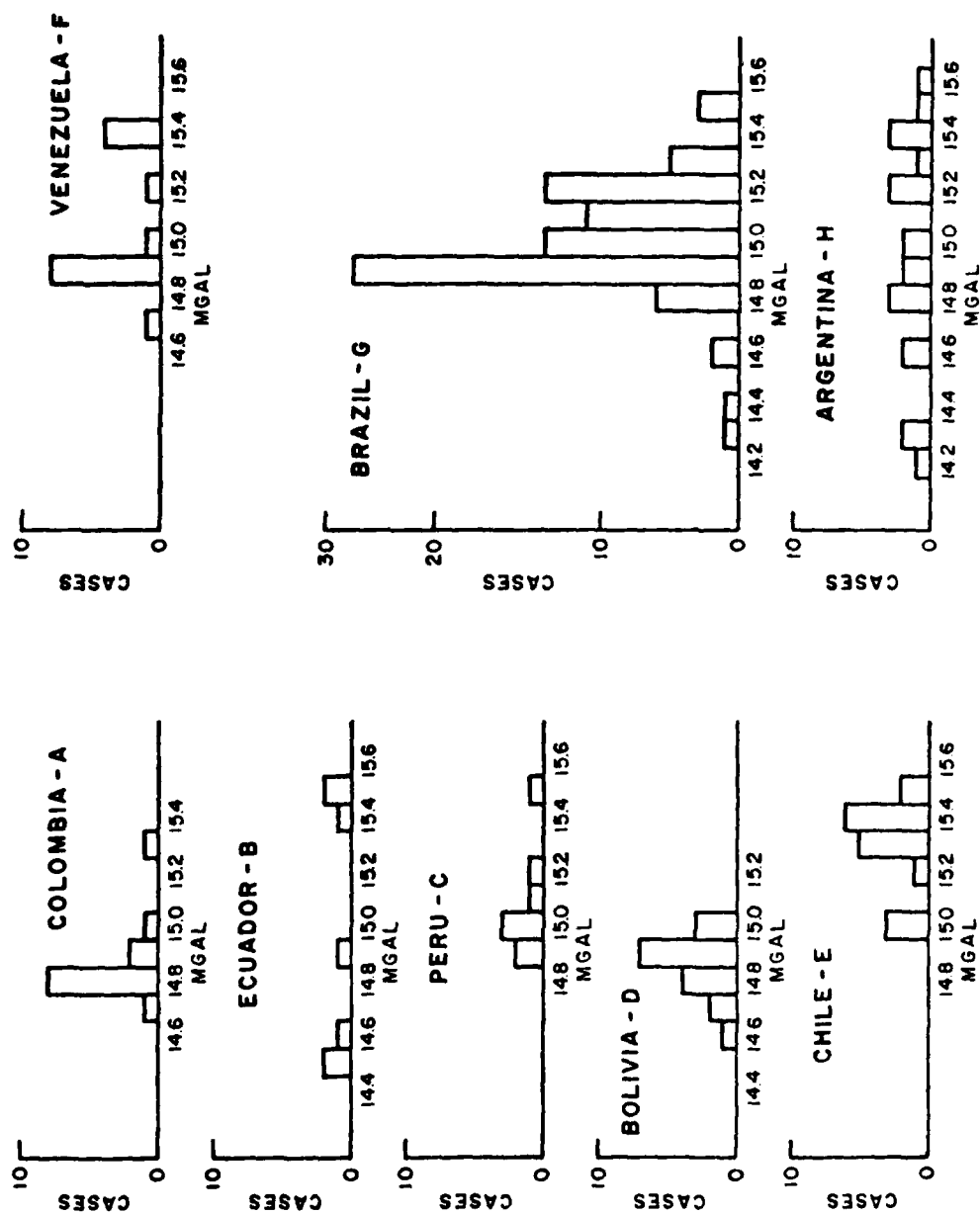


Fig. 13. Distribution plots of differences in Woollard and Rose (1963) values and IGSN 71 values in South America. A - Colombia, B - Ecuador, C - Peru, D - Bolivia, E - Chile, F - Venezuela, G - Brazil, H - Argentina.

differences in values for all sites in Colombia. The predominant value is 14.8 mgal and 11 of the 13 values would show agreement to  $\pm 0.1$  mgal with this value. In Ecuador (Figure 13-B) the spread in values is large (14.5 to 15.5 mgal); no central tendency in values is indicated, and the average value is 15.0 mgal. In Peru (Figure 13-C) the small sample of data indicate a predominant value of 15.0 mgal; 6 of the 8 values do not depart by more than 0.1 mgal from this value. In Bolivia (Figure 13-D), the distribution, although somewhat skewed, indicates a predominant value of 14.9 mgal, and 14 of the 17 values do not depart by more than 0.1 mgal from this value. In Chile (Figure 13-E), which involves a large change in latitude, but where most of the sites are at relatively low elevations, the bimodal distribution with peaks of 15.0 mgal and about 15.35 mgal is to be expected because of the difference in gravity standard brought out at the gravity standardization bases.

As no difference in gravity standard was suggested by the comparisons at the gravity standardization bases in eastern South America, any skewness or bimodal distribution of the differences in the Woollard and Rose and IGSN values in this area are presumably related to tares. This is the situation suggested in Figure 13-F for Venezuela where the dominant difference in values is 14.9 mgal with a secondary peak at 15.4 mgal. In Figure 13-G, which shows the data for Brazil and includes a few sites in the Guianas for which there are comparative data, the distribution pattern is similarly bimodal. The predominant difference in values

occurs at 14.9 mgal and at 15.2 mgal. Figure 13-II, which shows the data for Argentina plus single values for Paraguay and Uruguay, indicates no pronounced central tendency for the difference in values. The spread in values is abnormally large and the average value is about 15.0 mgal.

If the above differences in Woollard and Rose (1963) and IGSN 71 values are plotted as a function of absolute gravity, it is found that the indication of a difference in gravity standard from that of the IGSN values at the gravity standardization bases in the Andean region pertains to all of the Woollard and Rose values in South America. Figure 14-A is the plot of the differences in values as a function of absolute gravity at all sites in western South America coded to define the country to which the values pertain. Most of the values define a single alignment of values having the same mathematical expression as was defined at the gravity standardization bases; namely,

$$X = 14.7 + 0.2 (\text{Woollard Rose value} - 977.0 \text{ gal}).$$

A second parallel sector as a consequence of a tare of +0.55 mgal which involves 3 sites in Ecuador and 1 site each in Colombia and Peru -- all lie on the eastern (jungle) side of the Andes. That this same difference in gravity standard applies to values in eastern South America is brought out in Figure 14-B, which shows the differences in values grouped as before for Venezuela, Brazil and Argentina. Alignment (1), which involves most of the values for Venezuela and Brazil conform to that defined for the principal alignment of values in the Andean region. Alignment (2)

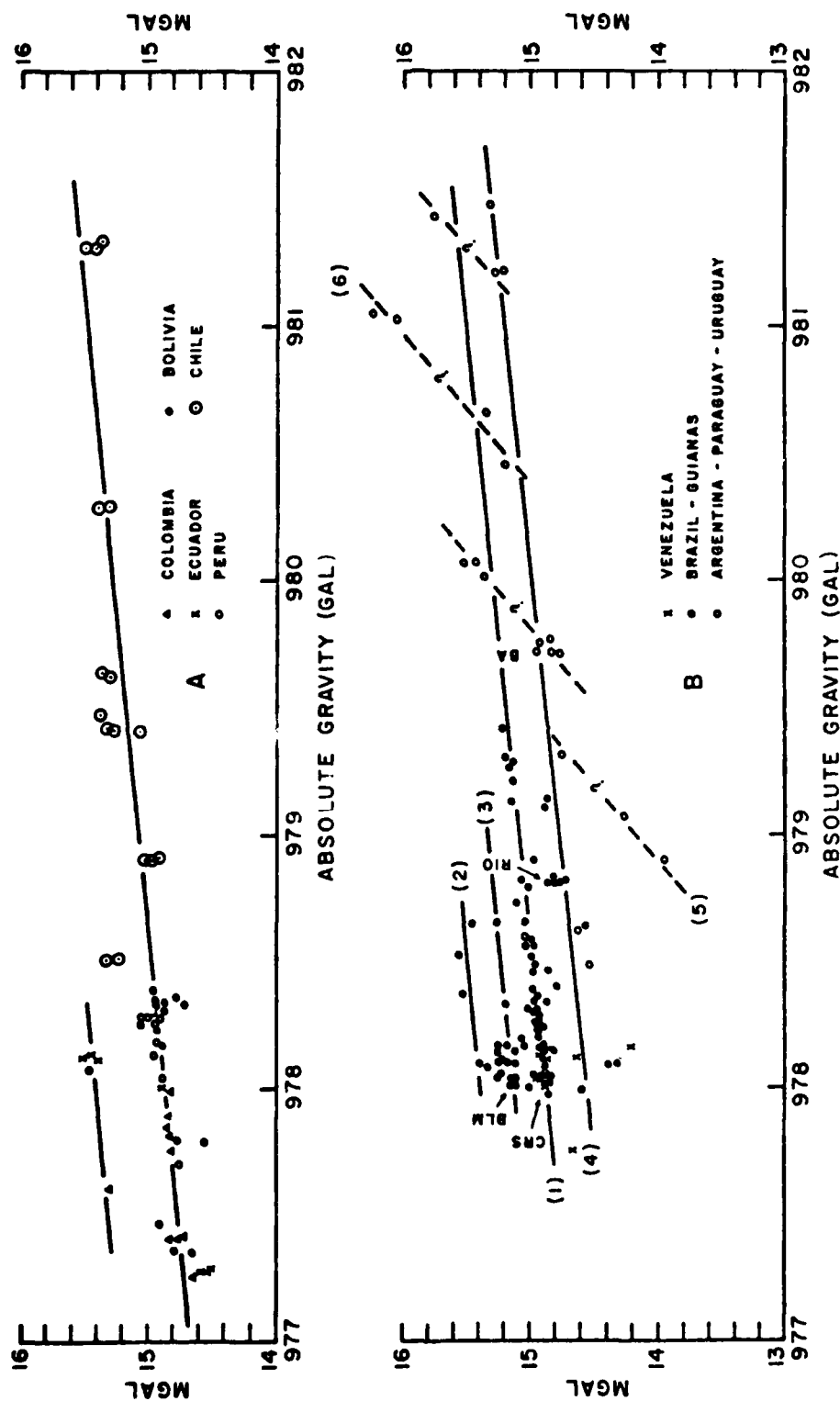


Fig. 14. Relation of differences in Woollard and Rose (1963) and IGSN 71 values to absolute gravity in South America. A - Colombia, Ecuador, Peru, Bolivia, and Chile. B - Venezuela, Brazil, the Guianas, Argentina, Uruguay, and Paraguay; CRS - Caracas; BLM - Belem; RIO - Rio de Janeiro; BA - Buenos Aires.

conforms to that for the secondary alignment of values in the Andean region and involves sites in the jungle area of Brazil. Alignment (3), which includes the Belem gravity standardization base, indicates that a tare occurred between Caracas, Venezuela and Belem, Brazil. The displacement of values from alignment (3) to alignment (4) indicates a negative tare between Belem and Rio de Janeiro. The apparent high angle parallel alignments of values in the data for Argentina are probably fortuitous, for although the relations are suggestive of those noted in Alaska and Mexico, the slopes are in opposite sign. It is more likely that the four values that depart significantly from alignments (1) and (4) are related to tares. The difference of 0.02 mgal per 1000 mgal in gravity standard indicated as characteristic of the Woollard and Rose values in South America, however, appears to be real, and is believed to be related to an undetected change in instrument calibration.

#### COMPARISON OF WOOLLARD AND ROSE (1963) AND IGSN 71 VALUES IN EUROPE AND AFRICA

The distribution plot for the differences in the Woollard and Rose (1963) and IGSN 71 values in Europe is shown in Figure 15-A. A bimodal distribution is indicated with predominant differences in values at 14.7 mgal and 14.9 mgal. However, 90% of the 68 values fall within bounds of  $\pm 0.2$  mgal for a mean average of 14.7 mgal.

In Africa (Figure 15-B) the distribution in values is similarly bimodal, with peaks at 14.2 mgal and 14.7 mgal. This

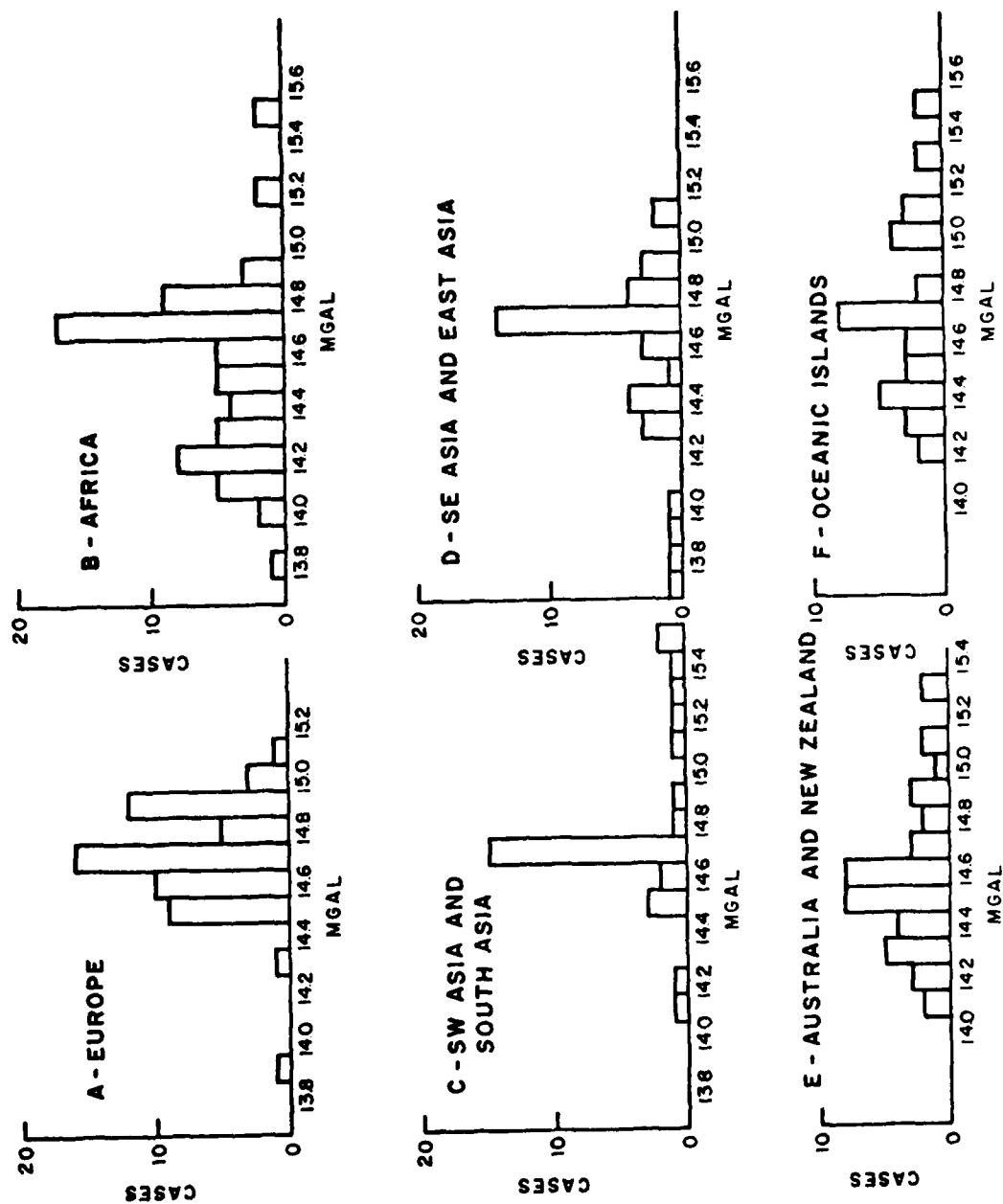


Fig. 15. Distribution plots of differences in Woollard and Rose (1963) values and IGSN 71 values in eastern hemisphere. A - Europe. B - Africa. C - South-west and Southern Asia. D - Southeast and East Asia. E - Australia and New Zealand. F - Oceanic Islands.



distribution indicates a significant tare of 0.5 mgal that affects about 40% of the values.

The reality of the tares suggested by the bimodal nature of the distribution plots is brought out when the differences in values are plotted as a function of absolute gravity. Figure 16-A is the plot for the values in Europe, and two distinct alignments of values separated by 0.35 mgal are suggested. These alignments, if real, define a difference in gravity standard from that defined by the IGSN 71 values, and indicate a slope much the same as that noted in South America -- namely, +0.2 mgal per 1000 mgal increase in gravity. This, however, could be fortuitous as two similar parallel alignments of values having zero slope and differences of 14.9 and 14.6 mgal would satisfy the data equally well. If this pattern is assumed correct, 90% of all the values would lie within  $\pm 0.15$  mgal of one or the other alignments.

The plot of the differences of the Woollard and Rose and IGSN 71 values as a function of absolute gravity in Africa (Figure 16-B), indicates no discernible difference in gravity standard from that of the IGSN 71 values. The pattern of tares brought out when the standardization bases were considered, however, is evident in that there are two alignments of values separated by 0.5 mgal. Alignments (1), which defines a mean datum difference of 14.7 mgal includes all the East African sites as well as those in North Africa except for sites in Ethiopia. Alignment (2), which is affected by the tare of -0.5 mgal, applies to all values between Nairobi and Johannesburg, and the

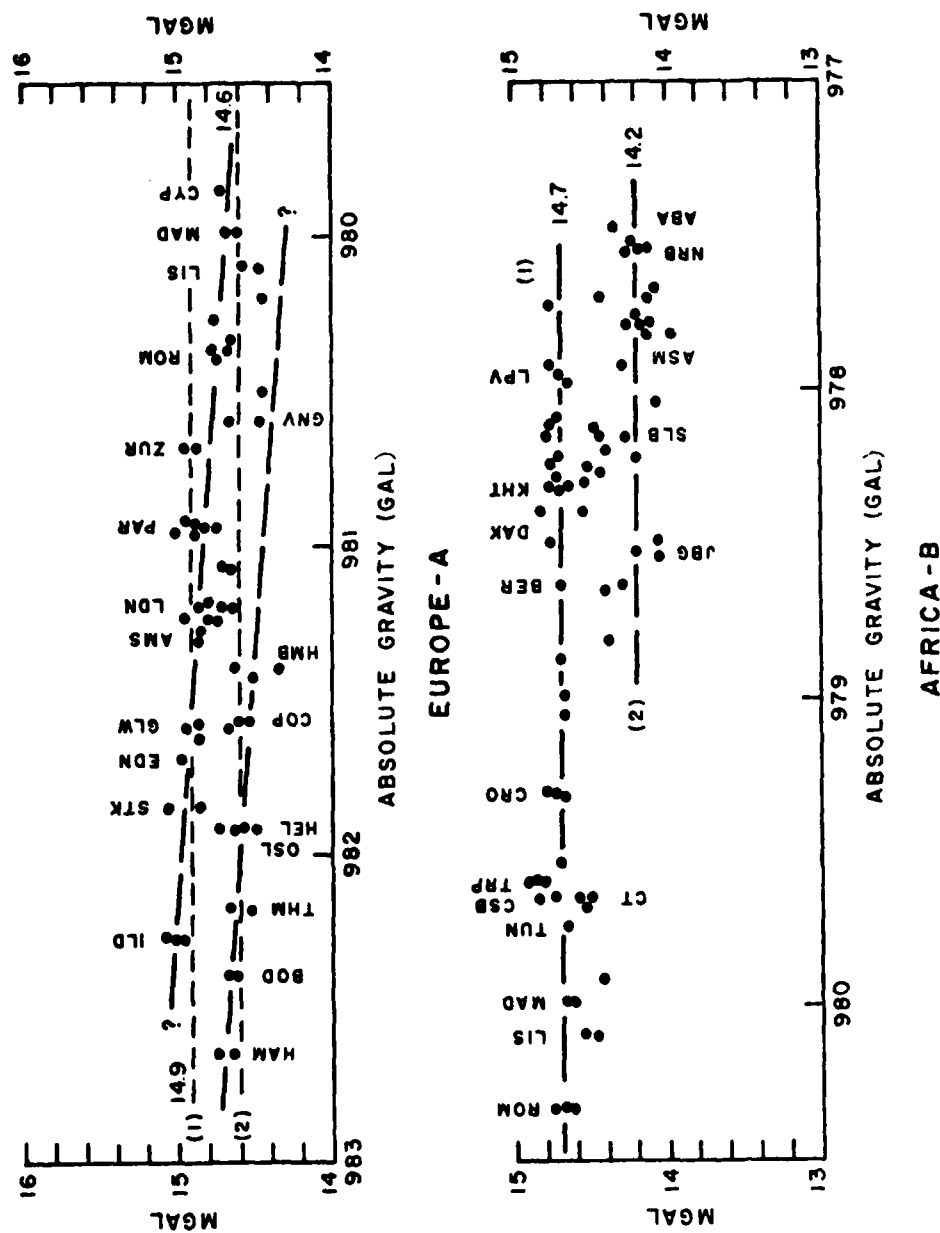


Fig. 16. Relation of differences in Woollard and Rcese (1963) and IGSN 71 values to absolute gravity in Europe and Africa.

A - Europe; Alignment (1) - ILD - Iceland; STK - Stockholm; EDN - Edinburgh; GLW - Glasgow; AMS - Amsterdam; LON - London; PAR - Paris; ZUR - Zurich. Alignment (2) - HAM - Hammerfest; BOD - Bodo; THM - Trondheim; OSL - Oslo; HEL - Helsinki; COP - Copenhagen; HVB - Hamburg; GNV - Geneva; ROM - Rome; LIS - Lisbon; MAD - Madrid; CYP - Cyprus. B - Africa; Alignment (1) - ROM, LIS, MAD as in A. TUN - Tunis; CT - Capetown; CSB - Casablanca; TRP - Tripoli; CRO - Cairo; BER - Beira; DAK - Dakar; KHT - Khartoum; LPV - Leopoldville. Alignment (2) - JBC - Johannesburg; SLB - Salisbury; ASM - Asmara; NRB - Nairobi; ABA - Addis Ababa.

sites in Ethiopia.

COMPARISONS OF WOOLLARD AND ROSE (1963) AND IGSN 71 VALUES IN  
THE PACIFIC SECTOR AND OTHER AREAS

For comparing the Woollard and Rose values with IGSN 71 values in the Pacific and other areas, the data are subdivided by areas in separate series of measurements. These are: (1) Southeast and Southern Asia; (2) Southeast and East Asia; (3) Australia and New Zealand, and (4) oceanic islands in the Pacific, Indian and Atlantic Oceans.

Southwest-South Asia Sector:

In Figure 15-C, the distribution plot of the differences in the Woollard and Rose values and the IGSN 71 values in Southwest and southern Asia is shown; the dominant value characterizing 48% of the 48 sites is 14.7 mgal. A similar value applies to sites in Southeast and East Asia and is brought out in Figure 15-D. Of the 34 sites involved 42% indicate a difference of 14.6 mgal. However, the wide spread in values in both areas suggests either that some of the observations were poor or else that there were some differences in some of the sites.

When the differences in the Woollard and Rose and IGSN 71 values in the above two sectors are plotted as a function of absolute gravity, the data for Southwest and southern Asia (Figure 17-A) indicate that whereas no difference in gravity standard is indicated in Turkey, the Persian Gulf region and Pakistan, there is a problem with the data for India. Either there is a marked difference in gravity standard for the values in India and

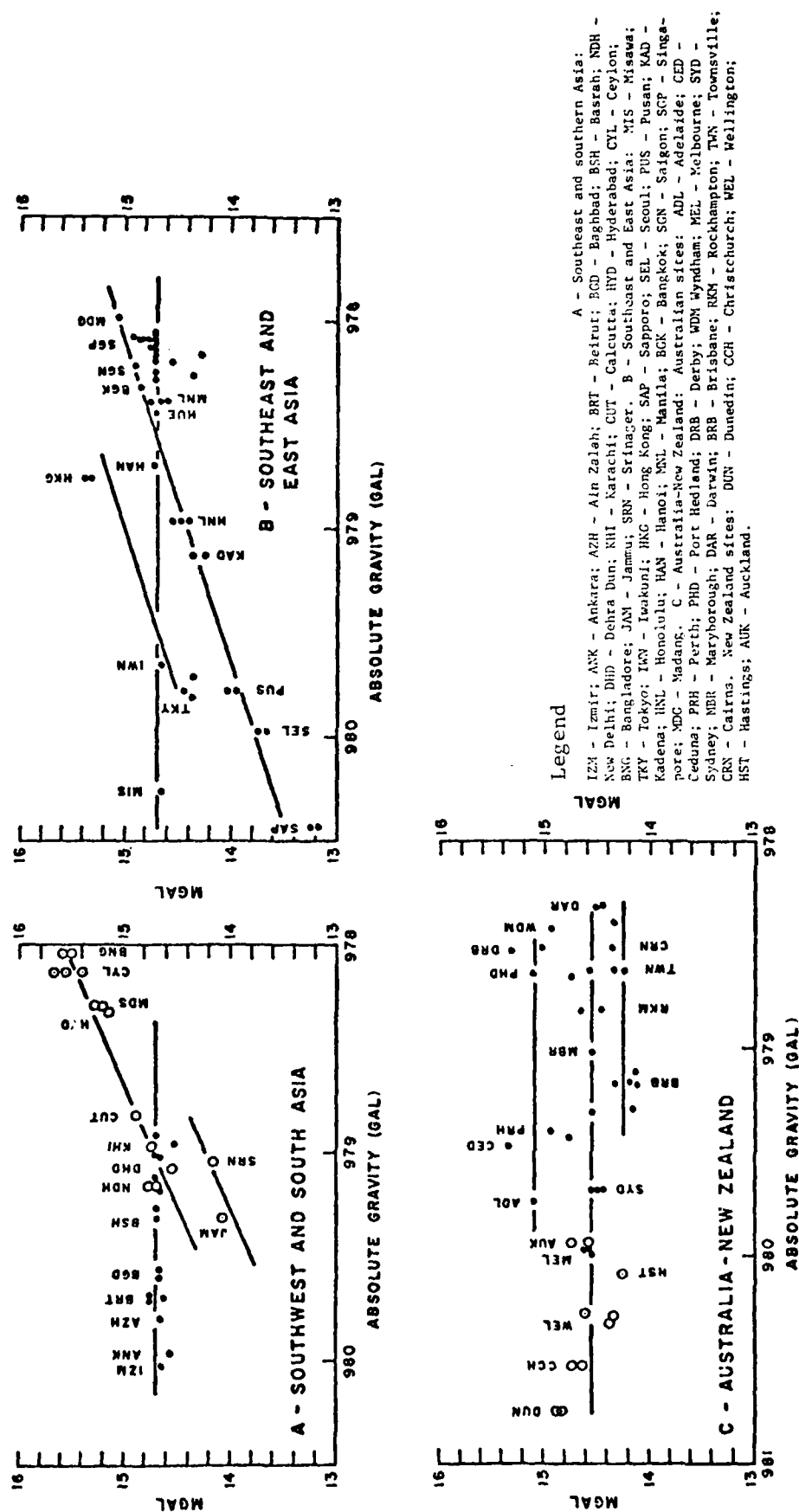


Fig. 17. Differences in Woollard and Rose (1963) values and IGSN 71 values in Asian and Australian New Zealand sectors as a function of absolute gravity.

Ceylon as well as a tare, or there are two tares in opposite sign. The latter interpretation is regarded as being correct as nearly all of the values represented in Figure 17-A were determined as part of the same global series of observations using two Worden gravimeters. This interpretation is reinforced by the dominant difference value of 14.7 mgal brought out in the distribution plot of differences (Figure 15-C). It is much more likely, therefore, that the southern Indian observations are offset from those in central India by a tare that was not properly handled in reducing the data, as is clearly the case for the two observations (Jammu and Srinagar) in northern India.

#### Southeast-East Asia Sector:

The distribution plot for the differences in Woollard and Rose and IGSN 71 values in Southeast and East Asia (Figure 15-D) is very similar to that for Southwest and South Asia in that although there is a wide spread in values, one value is dominant (14.7 mgal). When the differences in values are plotted as a function of absolute gravity (Figure 17-B) relations are similar to those depicted in Figure 17-A for Southwest Asia and southern Asia. The data can be interpreted as defining a difference in gravity standard plus tares, or as defining no difference in gravity standard plus tares. As in southwest and southern Asia, the latter interpretation is regarded as being the correct one.

#### Australia - New Zealand Sector:

The distribution plot of the differences in the Woollard and Rose values and IGSN 71 values in Australia and New Zealand

(Figure 15-E) indicates what appears to be a trimodal distribution of values. The dominant value is about 14.55 mgal and the secondary peaks occur at 14.3 mgal and 14.9 mgal. When these values are plotted as a function of absolute gravity (Figure 17-C), it is seen that although no difference in gravity standard from that of the IGSN values is suggested, there are three parallel alignments of values separated by apparent tares of about -0.3 mgal and +0.6 mgal relative to the principal alignment.

Oceanic Islands Sector:

The distribution plot of the differences in the Woollard and Rose values and IGSN 71 values on oceanic islands (Figure 15-F) suggests three groupings of values corresponding to differences of 14.4 mgal, 14.7 mgal and 15.0 mgal. In considering these differences in values as a function of absolute gravity, the data were segregated into groups along with the land base values to which each set of island observations were tied in order to better define any difference in gravity standard from that of the IGSN 71 values. In Figure 18-A, the data are shown for the Atlantic Ocean sector with Glasgow, Scotland; Goose Bay, Labrador; Caribou, Maine; Washington, D.C. and Charleston, South Carolina representing land base sites for the northern sector, and Panama, Caracas, Venezuela and Recife and Rio de Janeiro, Brazil representing land base points for the southern sector. Alignment (1) indicates that the values for Guantanamo, Cuba; San Juan, Puerto Rico; and the Azores lie on the same line as that defined for Goose Bay, St. John, Newfoundland, Washington and Charleston and indicate a

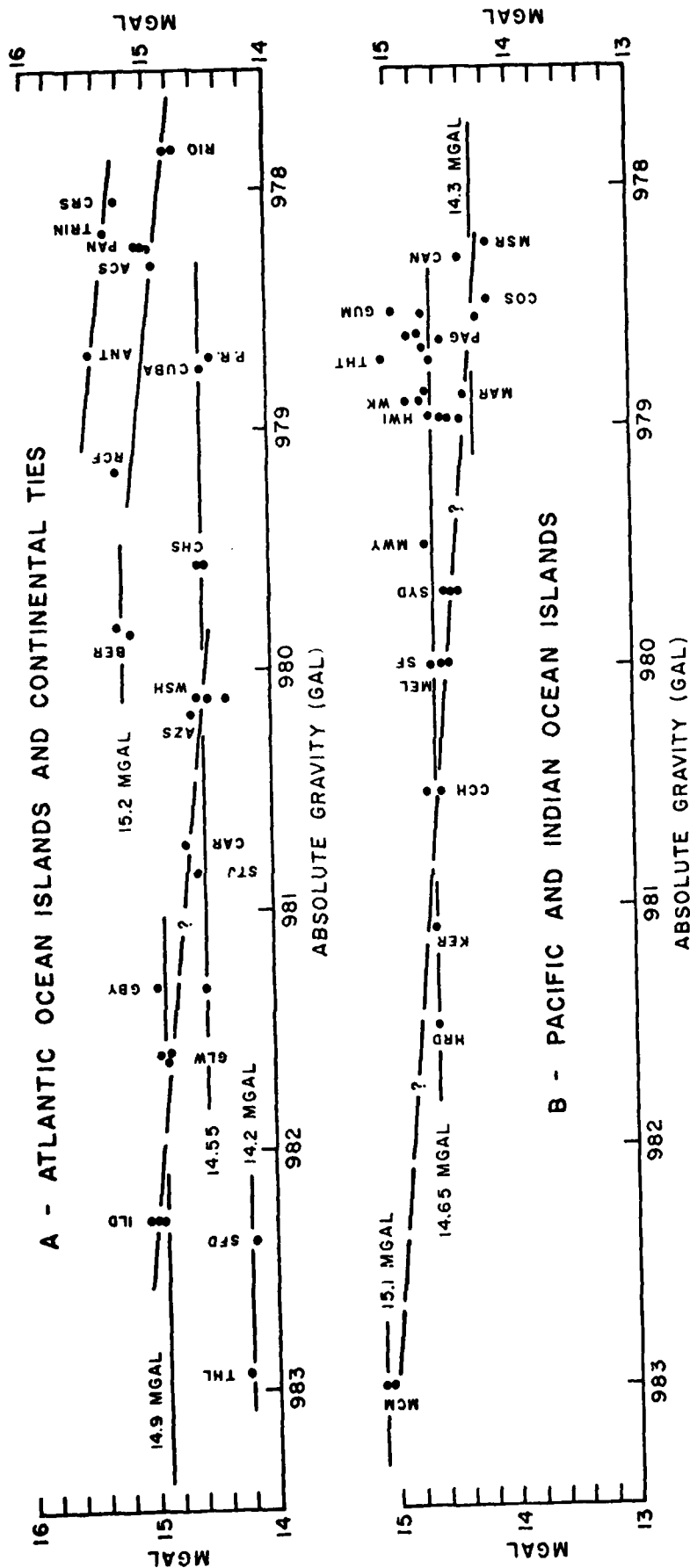


Fig. 18. Differences in Wollard and Rose (1963) values and IGSN 71 values on oceanic islands. A - Atlantic Ocean and continental tie bars: ILD - Iceland; GLW - Glasgow; GBY - Goose Bay; STJ - St. Johns; CAR - Caribou; AZS - Azores; WSH - Washington; BER - Bermuda; CHS - Charleston; RCF - Recife; ANT - Antiqua; ACS - Ascension; TRIN - Trinidad; CRS - Caracas; PAN - Panama; THL - Thule; SFD - Sondre Stromfjord. B - Pacific and Indian Ocean Islands: MCM - McMurdo; HRD - Heard; KER - Kerguelen; CCH - Christchurch; MEL - Melbourne; ST - San Francisco; SYD - Sydney; MWY - Midway; HWI - Hawaii; WK - Wake; MAR - Mauritius; THT - Tahiti; PAG - Pago Pago; GUM - Guam; COC - Cocos; CAN - Canton; MSR - Madagascar.

datum difference of 14.55 mgal with no difference in gravity standard from that of the IGSN 71 values. The values for Iceland (Keflavik and Reyjavik), however, which were connected from Goose Bay en route to Glasgow, Scotland, similarly indicate no difference in gravity standard from that of the IGSN 71 values, but a datum difference of 14.95 mgal. Although a slope could be fitted to this portion of the data from Washington this is regarded as fortuitous. This slope, however, is believed to apply to the data for Ascension Island in the South Atlantic area and its connections to Rio de Janeiro as well as to the data for Trinidad, Antigua and Caracas. The offsets in values for Bermuda (15.2 mgal) and for Thule and Sondre Stromfjord in Greenland (14.2 mgal) are believed to result from tares.

In the Pacific area if the three values for the Indian Ocean (Mauritius, Madagascar and Cocos Island) are disregarded along with the value for McMurdo, Antarctica, there is no evidence for any departure in gravity standard from that of the IGSN 71 values, and the datum offset indicated is 14.56 mgal. The sites in the Indian Ocean appear to have a datum difference of about 14.3 mgal and the value at McMurdo, Antarctica, indicates a difference in values of 15.1 mgal. That this last is a consequence of a tare rather than any difference in gravity standard is indicated by the data for Heard and Kerquelen Islands, which were observed on the same trip based out of Melbourne, Australia. The apparent alignment of values indicating a difference in gravity standard between McMurdo and Madagascar is therefore purely fortuitous.



### SUMMARY STATEMENT

In summary it would appear that the discrepancies in the Woollard and Rose (1963) values relative to the IGSN 71 values fall into three categories. The first, and by far the most extensive group of values, which characterizes all of North America (except Alaska and Mexico), Africa, Australia, New Zealand, Southwest and Southeast Asia and most of the Pacific and North Atlantic sectors, involves no difference in gravity standard from that incorporated in the IGSN 71 values, although there are regional differences in the datum offset values because of tares. The second group, which is associated with all measurements in South America and the South Atlantic sector, are characterized by a gravity standard that differs by +0.2 mgal per 1000 mgal increase in gravity from that incorporated in the IGSN 71 values. As with the first group, there are datum offsets due to tares between different segments of the data. The third group, which applies to the data for Alaska and Mexico, are characterized by a much more pronounced difference in gravity standard, of the order of 1.5 mgal per 1000 mgal change, as well as tares.

Despite the above diversity in the patterns of agreement between the Woollard and Rose (1963) values and the IGSN 71 values, the mean differences in values do not vary greatly, and as the degree of deviation on a worldwide basis is a measure of overall reliability, a distribution plot is shown in Figure 19 of the differences at all sites (787) at which comparisons could be made. As seen from Figure 19, a near-Gaussian distribution is indicated

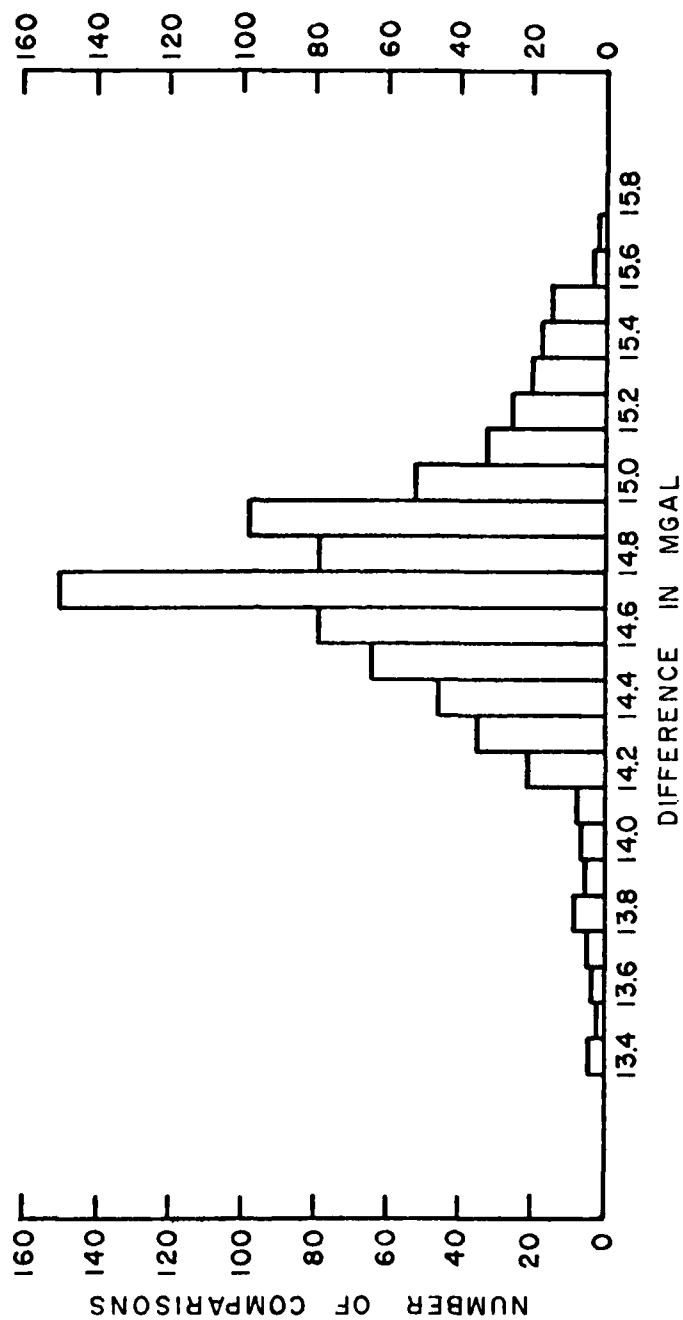


Fig. 19. Distribution plot of differences in Woollard and Rose and ICSN 71 values at all sites worldwide.

and the dominant value of difference (14.7 mgal) corresponds to that for the Madison, Wisconsin base value used by Woollard and Rose. Agreement to 0.1 mgal or better with this value is indicated at 196 sites (25% of the value). Agreement to 0.2 mgal or better is indicated at 474 sites (60% of the values), and agreement to 0.3 mgal or better is indicated at 576 (73% of the values). The standard deviation from the mean value of 14.7 mgal is 0.25 mgal. As this is without any allowance for any uncertainties in the IGSN 71 values or for the differences in the IGSN 71 values of Morelli et al (1974) and DMAAC, the overall degree of reliability conceivably could be somewhat better than indicated by the standard deviation. However, as brought out in the area-by-area comparisons, the quality of the Woollard and Rose (1963) values varies with area, and if these values are to be used to, in effect, extend the IGSN 71 network of base values, or to convert gravity surveys based on Woollard and Rose values to IGSN 71 equivalence, it has to be on the basis of these areal comparisons and individual site value differences. To facilitate such conversion of the Woollard and Rose values, tables of the differences in these values relative to IGSN 71 values for all individual sites for which there are comparative data have been prepared and filed with the SEG office. In the case of Woollard and Rose sites for which there are not comparative IGSN 71 values, the graphical areal comparisons included in this paper should permit IGSN 71 values to be approximated with a reasonable degree of reliability. In general, such approximations should have a reliability of about  $\pm 0.25$  mgal or better.

## Appendix I

Tables of Differences in Gravity (Gravimeter) Values  
Given in SEG Special Publication International Gravity Measurements  
(Woollard and Rose, 1963) and IGSN 71 Gravity Values  
As Determined by Morelli et al. (1974) and  
By the U. S. Defense Mapping Agency Aerospace Center (unpublished)

### Preface

The values given in the following tables are only for sites that are believed to be the same and as described in SEG special publication International Gravity Measurements . Values that appear to be for the same site, but where the difference in values appears to be anomalous because of a site difference are indicated by a question mark. No values are included for sites that clearly are not the same. Otherwise, there was no editing of the 787 comparative values listed.

The tables are divided into two groups because of differences in coverage and slight differences in the IGSN 71 values as determined by Morelli et al. (1974) and the U.S. Defense Mapping Agency Aerospace Center (DMAAC). The differences in values are a consequence of differences in gravity standard of the order of 0.025 mgal per 1000 mgal that are not consistent in sign in going from one continental area to another. There are also datum offsets of the order of 0.02 to 0.04 mgal between continental areas. For these reasons, comparisons at the gravity standardization (pendulum) bases and their excenters are considered separately ( Appendix I) and the IGSN 71 values used are those of Morelli et al. (1974) which give more complete coverage for these sites than do the DMAAC values. However, the more restricted number of DMAAC IGSN 71 values for these bases are also listed for comparative purposes.

Tables in Appendix II are for all Woollard and Rose bases for which there are comparative IGSN 71 values. The IGSN 71 values of Morelli et al. (1974) are used wherever possible, and the DMAAC values while for comparative purposes at some sites, are in general only listed where there are no IGSN 71 values by Morelli et al. (1974). In all cases the DMAAC values are marked with an asterisk. As the standard deviation between the IGSN 71 values as determined by Morelli et al. (1974) and DMAAC at the 239 sites where comparisons could be made is  $\pm 0.01$  mgal with 88 percent of the values agreeing to  $\pm 0.02$  or better, this mixing of IGSN 71 values from two sources is not a matter of major concern in establishing the differences between the Woollard and Rose (1963) values and the IGSN 71 values.

For a complete analysis of the patterns of difference in the Woollard and Rose values and IGSN 71 values on an areal basis, see "The Global Standardization of Gravity"(text of this report). For an analysis of the reliability of the IGSN 71 values particularly as regards the Potsdam datum correction and absolute gravity standard incorporated in these values as determined by Morelli et al. (1974), see "The New Gravity System (Woollard and Godley, 1980).

Table I. Gravity Standardization (Pendulum) Bases and Excenters  
in North America

A. Western and Mid-Continent Series	68
B. East Coast series	74

Table II. Gravity Standardization (Pendulum) Bases and Excenters  
in South America

A. West Coast (Andean) Series	77
B. East Coast (Atlantic) Series	79

Table III. Gravity Standardization (Pendulum) Bases and  
Excenters in Europe

81

Table IV. Gravity Standardization (Pendulum) Bases and  
Excenters in Africa

A. Mid-Continent Series	85
B. West Coast Series	87

Table V. Gravity Standardization (Pendulum) Bases and  
Excenters in Pacific-Australian Series  
including Antarctica

88

Table VI. Gravity Standardization (Pendulum) Bases and  
Excenters in India, Ceylon and Iceland

93

Table I-A  
Comparison of Woollard and Rose Gravimeter Values and IGSN 71  
Values at Pendulum sites and their Excenters in North America

A - Western and Mid-Continent Series

Code: GW - Woollard and Rose pendulum site number (Intl. Gravity Meas. SEG 1963)  
Dom. and USCGS: pendulum sites of Dominion Obs. and US Coast and Geod. Survey  
WA - Woollard and Rose airport site number (Intl. Gravity Meas. SEG 1963)  
WH - Woollard and Rose harbor site number (Intl. Gravity Meas. SEG 1963)  
'A', 'B', 'C' - Pendulum or absolute gravity site. Intl. Grav. Bur. Paris  
'J', 'K', 'L' - Airport or other excenter site. Intl. Grav. Bur. Paris

		(1) Woollard and Rose	(2) IGSN 71	1-2 Diff (mgal)	(3) IGSN 71 DMA AC	1-3 Diff (mgal)
ALASKA						
<u>Point Barrow</u>						
GW 105	Arctic Rsch. Lab.	982.6996	"B" .68500	+14.60		
GW 5	" "	982.6998	"A" .68518	+14.62	.68517	+14.63
WA 280	Airport	982.6998	"K" .68521	+14.59		
<u>Fairbanks</u>						
GW 6	U of A Geophys. Inst.	982.2462	"A" .23171	+14.49	.23170	+14.50
GW 27	Fort Wainwright	982.2444	"B" .22991	+14.49		
Absolute	Rm 1, Patty Bldg Univ. Alaska	982.2495	"C" .23500	+14.50		
WA 279	Int'l. Airport	982.2464	"K" .23197	+14.43		
WA 347	Ft Wainwright AP	982.2439	"J" .22937	+14.53		
<u>Anchorage</u>						
USCGS	Elmendorf AFB	981.9400	"A" .92519	+14.81		
WA 474	" "	981.9382	"J" .92356	+14.64		
WA 323	Int'l. Airport	981.9204	"K" .90586	+14.54	.90582	+14.58



Table I-A (cont.)

	(1) Woollard and Rose	(2) IGSN 71	1-2 Diff (mgal)	(3) IGSN 71 DMA AC	1-3 Diff (mgal)
CANADA					
<u>Watson Lake, Yukon Territory</u>					
Dom Obs.	Airport manager	981.7150	"A" .70039	+14.61	
WA 476	AP outside term.	981.7143	"K" .69998	+14.32	
<u>Whitehorse, Yukon Territory</u>					
GW 26	Airport Pump House	981.7486	"B" .73425	+14.35	
WA 188	Airport	981.7487	"J" .73425	+14.45	
<u>Fort Nelson, British Columbia</u>					
Dom Obs	Hotel	981.6828		.66817	+14.63
WA 182	Airport	981.6929	"J" .67839	+14.51	
<u>Fort St. John, British Columbia</u>					
GW 27	AP Adm. Bldg.	981.4059	"A" .39121	+14.69	
WA 478	Airport outside term.	981.4055	"J" .39078	+14.72	+14.71
<u>Vancouver, British Columbia</u>					
Dom Obs	"	980.9352	"A" .92068	+14.52	+14.52
WA 186	Int'l. Airport	980.9299	"J" .91541	+14.49	
<u>Grande Prairie, Alberta</u>					
Dom Obs	Post Office	981.3180	"A" .30322	+14.78	+14.80
GW 10	School	981.3175	"B" .30285	+14.65	
WA 183	Airport tower	981.3158	"J" .30099	+14.81	
<u>Edmonton, Alberta</u>					
Pend.	Univ. Alberta	981.1677	"A" .15309	+14.61	+14.61
GW 25	"	981.1678	"B" .15316	+14.64	

Table I-A (cont.)

	(1) Woollard and Rose	(2) IGSN 71	1-2 Diff (mgal)	(3)	
				IGSN 71 DMA AC	1-3 Diff (mgal)
GW 5	Univ. Alberta	981.1672	"C" .15279		+14.41
WA 181	Mun. Airport	981.1729	"K" .15838		+14.52
WA 282	RCAF NMAO	981.1803	"M" .16584		+14.46
	<u>Calgary, Alberta</u>				
GW 32	AP Generator Bldg	980.8281	"A" .81355		+14.55
WA 180	Terminal	980.8288	"J" .81425		+14.55
Dom Obs	Public Library	980.8286	"C" .81406	.81406	+14.54
	<u>Lethbridge, Alberta</u>				
GW 33	Post Office	980.7589	"A" .74462	.74461	+14.29
GW 12	Mun. Bldg	980.6083	"C" .74418		+14.12
WA 184	Airport	980.7538	"J" .73915		+14.65
	<u>UNITED STATES</u>				
	<u>Seattle, Washington</u>				
GW 104	Univ. Wash.	980.7388	"A" .72434	.72434	+14.46
WA 170	Int'l. Airport	980.7765	"K" .76202		+14.48
	<u>Cutbank, Mont.</u>				
GW 34	Airport	980.6085	"B" .59383	.59377	+14.73
	<u>Great Falls, Montana</u>				
GW 4	Roosevelt Sch.	980.5269	"A" .51230	.51229	-14.59
WA 482	Mun. Airport	980.5137	"J" .49911		+14.59
WA 243	Malmstrom AFB	980.5291	"K" .51452		+14.58

Table I-A (cont.)

		(1) Woollard and Rose	(2) IGSN 71	1-2 Diff (mgal)	(3) IGSN 71 DMA AC	1-3 Diff (mgal)
	<u>Billings Montana</u>					
GW 25	AP Hangar	980.3710	"A" .35637	+14.63	.35637	+14.63
WA 122	Terminal	980.3717	"K" .35737	+14.33		
	<u>Sheridan, Wyoming</u>					
GW 36	AP Hangar	980.2264	"A" .21205	+14.35		
WA 179	Field	980.2265	"J" .21214	+14.36	.21214	+14.36
	<u>Casper Wyoming</u>					
GW 37	AP Hangar	979.9558			.94133	+14.47
WA 177	Field	979.9562	"J" .94159	+14.61		
	<u>Cheyenne, Wyoming</u>					
GW 38	AP Cafe	979.7006	"A" .68618	+14.42	.68619	+14.41
GW 17	Hangar	979.7008	"B" .68630	+14.50		
WA 178	Field	979.7008	"J" .68623	+14.57		
	<u>Denver, Colorado</u>					
Absolute	Univ. Denver	979.6123	"A" .59768	+14.62	.59770	+14.60
GW 39	Chamberlain Obs.	979.6117	"B" .59710	+14.60		
WA 89	Stapleton Field	979.6335	"J" .61897	+14.53		
	<u>San Francisco, California</u>					
GW 54	Golden Gate Park	979.9867	"A" .97213	+14.57		
WA 87	Int'l. Airport	979.9885	"J" .97381	+14.69		

Table I-A (cont.)

		(1) Woollard and Roge	(2) IGSN 71	1-2 Diff (mgal)	(3) IGSN 71 DMA AC	1-3 Diff (mgal)
WA 86	Int'l. Airport	979.9883	"K" .97375	+14.55		
WA 202	Travis AFB	978.9898	"P" .97538	+14.42		
	<u>Huron, South Dakota</u>					
GW 24x	Hangar (USCG 1200)	980.4530			.43859	-14.41
	<u>Madison, Wisconsin</u>					
GW 31	Univ. Wis. Sci. Hall	980.3689	"A" .35422	+14.68	.35422	-14.68
WA 76	Truax Field	980.3725	"J" .35782	+14.68		
	<u>Chicago, Illinois</u>					
GW 23	Midway AP Hangar	980.2873	"A" .27262	+14.68		
WA 101	Midway Airport	980.2864	"J" .27179	+14.61		
	<u>Beloit, Kansas</u>					
GW 52	Phillips gas sta.	979.9981			.98359	+14.51
	<u>Tulsa, Oklahoma</u>					
GW 51	Univ. Tulsa	979.7661			.75146	+14.64
	<u>Amarillo, Texas</u>					
GW 50	Airport hangar	979.4235	"A" .40911	+14.39		
WA 67	AP Terminal	979.4234	"J" .40887	+14.53	.40887	+14.53
	<u>Houston, Texas</u>					
GW 18	Rice Univ.	979.2983	"A" .28372	+14.58	.23772	+14.58
WA 159	Old Int'l. Airport	979.2932	"J" .27866	+14.64		

Table I-A (cont.)

	(1) Woollard and Rose	(2) IGSN 71	1-2 Diff (mgal)	(3) IGSN 71 DMA AC	1-3 Diff (mgal)
<u>San Antonio, Texas</u>					
GW 40	Airport storeroom	979.1975	"A" .18273	+14.77	
WA 162	Airport field	979.1976	"J" .18286	+14.74	
WA 161	Airport Terminal	979.1973	"L" .18257	+14.73	

Table I-B

## Comparison of Woollard and Rose Gravimeter Values and IGSN 71

## Values at Pendulum sites and their Excenters in North America

## B - East Coast Series

	(1) Woollard and Rose	(2) IGSN 71	1-2 Diff (mgal)	(3) IGSN 71 DMA AC	1-3 Diff (mgal)
CANADA					
Ottawa, Ontario					
GWA 53A	Dominion Obs.	980.6208	"A" .60614		+14.66
GW 53	Geophys Lab.	980.6217	"B" .60710		+14.60
WA 310	Mun. Airport	980.6187	"L" .60414		+14.56
UNITED STATES					
Woods Hole, Massachusetts					
GW 77	WH Ocean. Inst.	980.3273			
GW 77A	" " BM	980.3271		.31249	+14.81
WA 472	Hyannis Airport	980.3400		.32541	+14.59
Palisades, New York					
GW 1	Lamont-Doherty	980.2596			
WA 133	Kennedy Airport	980.2261	"K" .21135	.21134	+14.76
WA 132	LaGuardia Airport	980.2825	"S" .26777		+14.73
Princeton, New Jersey					
GW 78	Univ. Guyot Hall	980.1783	"A" .16373		+14.57
GW 78A	Rm 14 Guyot	980.1776	"B" .16306		+14.54

Table I-B (cont.)

		(1) Woollard and Rose	(2) IGSN 71	1-2 Diff (mgal)	(3) IGSN 71 DMA AC	1-3 Diff (mgal)
Absolute	Palmer Lab.	980.1755	"C" .16098	+14.52		
WA 42	McGuire AFB	980.2128	"J" .19836	+14.44	.19835	+14.45
	<u>Washington, D. C.</u>					
USCCS	Commerce Pier	980.1188	"A" .10429	+14.51	.10430	+14.50
GW 2	Dept. Terr. Mag. CIW	980.1006	"D" .08605	+14.55		
Absolute	Old Bu. Stds.	980.0995	"E" .08486	+14.64		
WA 493	National Airport	980.1089	"K" .09440	+14.50		
Absolute	Bu. Stds. Gaithersburg Rm. 129, Bldg 202		"V" .10132			
	<u>Charleston, South Carolina</u>					
GW 90	Citadel Univ	979.5509	"A" .53635	+14.55	.53635	+14.55
WA 494	Mun. Airport	979.5667	"J" .55216	+14.54		
WA 148	Mun. Airport BM	979.5668	"K" .55227	+14.53		
WA 147	MATS Term.	979.5675	"L" .55298	+14.52		
	<u>Miami, Florida</u>					
GW 115	U.M. Marine Biol. Lab.	979.0356	"A" .02095	+14.65	.02095	+14.65
WA 278	Int'l. Airport	979.0528	"J" .03829	+14.51		
WA 11	Old EAL Term.	979.0543	"L" .03957	+14.73		
	<u>Key West, Florida</u>					
GW 116	US Naval Sta.	978.9692	"A" .95446	+14.54		
WH 39	" " gate	978.9686	"J" .95407	+14.53		

Table I-B (cont.)

	(1) Woollard and Rose	(2) IGSN 71	1-2 Diff (mgal)	(3) IGSN 71 DMA AC	1-3 Diff (mgal)
C - MEXICO - CENTRAL AMERICA Series					
<u>Monterey, Nuevo Leon</u>					
GW 21	Inst. Technology	978.8055	"A" .79069	.97069	+14.81
WA 190	Airport	978.8617	"J" .84705		+14.65
<u>Mexico City, D. F.</u>					
GW 43	Univ. Mexico	977.9414	"A" .92650		+14.90
GW 41	Tacubaya	977.9419	"O" .92715		+14.75
WA 189	Int'l. Airport	977.9701	"J" .95542	.95543	+14.67
WA 489	Int'l. Airport	977.9705	"L" .95599		+14.51
<u>Paso de Cortes</u>					
GW 42	TV station	977.5711	"A" .55636		+14.74
GW B	Cortes monument	977.6536	"C" .63832		+15.28
PANAMA					
GW 92	Balboa C.Z.	978.2417	"A" .22670		+15.0
92C	YMCA	978.2391	"O" .22400		+15.10
WA 4014	Tocumen AP	978.2665	"J" .25144	.25144	+15.06
WA 4004	Albrook AFB	978.2427	"S" .22772		+14.98
WH 1015	Rodman Navy Base	978.2376	"R" .22254		+15.06



Table II-A

Comparison of Woollard and Rose Gravimeter Values and IGSN 71  
Values at Pendulum Sites and their Excenters in South America

## A - West Coast (Andean) Series

		(1) Woollard and Rose	(2) IGSN 71	1-2 Diff (mgal)	(3) IGSN 71 DMA AC	1-3 Diff (mgal)
PANAMA						
GW 92	Balboa C.Z.	978.2417	"A" .22670	+15.00		
WA 4014	Tocumen AP	978.2665	"J" .25144	+15.06	.25144	+15.06
GW 92x	Balboa YMCA	978.2391	"O" .22400	+15.10		
WA 4004	Albrook AFB	978.2427	"S" .22772	+14.98		
WH 1015	Rodman Navy Base	978.2376	"R" .22254	+15.06		
COLOMBIA						
GW 106	Bogota IGM	977.4049	"A" .39011	+14.79	.39012	+14.78
Absolute	Bogota Univ. Nac.	977.4049	"C" .39014	+14.76		
WA 6112	AP Mun. Techo	977.4017	"J" .38691	+14.79		
WA 6145	Int'l. AP Eldorado	977.3954	"K" .38059	+14.81		
ECUADOR						
GW 94	Quito	977.2777	"A" .26319	+14.51		
WA 6121	Panagra AP	977.2860	"J" .27144	+14.56		
WA 6139	Mariscal Scure AP	977.2849	"K" .27038	+14.52		
PERU						
GW 93	Lima	978.2830	"A" .26794	+15.06	.26794	+15.06

Table II-A(cont.)

	(1) Woollard and Rose	(2) IGSN 71	1-2 Diff (mgal)	(3) IGSN 71 DMA AC	1-3 Diff (mgal)
WA 6126	Limatambo AP	978.2791	"J" .26408	+15.02	
WA 6140	Callao Int'l AP	978.3072	"K" .29218	+15.02	
BOLIVIA					
GW 95	La Paz	977.4671	"A" .45219	+14.91	+14.89
WA 6134	Braniff AP Term.	977.3528	"K" .33800	+14.80	
WA 6020	Panagra Term.	977.3487	"L" .33402	+14.68	
CHILE					
GW 99	Antofogasta	978.9045	"A" .88952	+14.98	+15.0
WA 6105	Cerro Moreno AP	978.8853	"K" .87030	+15.00	
WA 6135	old Cerro Moreno AP	978.8830	"L" .86804	+14.96	
GW 96	Santiago	979.4294	"A" .41411	+15.29	+15.33
WA 6110	Los Cerrillos AP	979.4500	"K" .43468	+15.32	
WH 1020	Valparaiso Pier 1	979.6362	"K" .62087	+15.33	
WH 1058	Valparaiso Lt. Hs.	979.6342	"L" .61890	+15.30	+15.33
GW 97	Punta Arenas	981.3159	"A" .30049	+15.41	+15.38
WA 6108	Old Term.	981.3122	"K" .29670	+15.50	
WA 6136	AP Term.	981.3130	"L" .29761	+15.39	
WH 1019	Port Adm. Bldg.	981.3363	"N" .32081	+15.49	

Table II-B

## Comparison of Woollard and Rose Gravimeter Values and IGSN 71

## Values at Pendulum sites and their Excenters in South America

## B - East Coast (Atlantic) Series

		(1) Woollard and Rose	(2) IGSN 71	1-2 Diff (mgal)	(3) IGSN 71 DMA AC	1-3 Diff (mgal)
VENEZUELA						
GW 107	Caracas	978.0399	"A" .02472	+15.18	.02474	+15.16
WA 6131	Maiguëtia AP	978.2460	"K" .23106	+14.94		
WH 1071	La Guayra Hrb.	978.2522	"L" .23724	+14.96		
BRASIL						
GW 108	Belem	978.0374	"A" .02224	+15.16	.02223	+15.17
WA 6032	Airport	978.0342	"K" .01897	+15.23		
WH 1012	Tide gage	978.0397	"O" .02459	+15.11		
WH 1055	Pier BM	978.0399	"N" .02463	+15.27		
GW 109	Rio de Janeiro	978.8047	"A" .78990	+14.80	.78990	+14.80
WA 6082	Galeao AP	978.7978	"J" .78305	+14.75		
WA 6081	Santos Dumont AP	978.8084	"L" .79355	+14.85		
WH 1060	Pier Da Praca Nana	978.8076	"Q" .79278	+14.82		
ARGENTINA						
GW 98A	Buenos Aires	979.7048	"A" .69003	+14.77	.69003	+14.77
Univ Base	Meter. Obs.	979.7060	"C" .69116	+14.84		
Univ Base	La Plata Obs.	979.7517	"O" .73685	+14.85		
WA 6002	Ezeisa AP	979.7317	"K" .71675	+14.95		

Table II-B(cont.)

		(1) Woollard and Rose	(2) IGSN 71	1-2 Diff (mgal)	(3) IGSN 71 DMA AC	1-3 Diff (mgal)
Mateo Pend.	Cordoba Astr. Obs	979.3419				
WA 6004	Cordoba AP	979.3271	"K" .31234	+14.76	.31232	+14.78
WA 6007	Mar del Plata AP	980.0181			.00273	+15.37
Mateo Pend.	Hotel Soldini, La Plata	980.0340				
WA 6010	Aeronaval AP	981.2066	"K" .19138	+15.22	.19134	+15.26
Mateo Pend.	Rio Gallegos School	981.2126				
Mateo Pend.	Ushuaia Penitentiary	981.4807	"A" .46539	+15.31		

Table III  
Comparisons of Woollard and Rose Gravimeter Values and IGSN  
71 Values at Pendulum sites and their Excenters in Europe

		(1) Woollard and Rose	(2) IGSN 71	1-2 Diff (mgal)	(3) IGSN 71 DMA AC	1-3 Diff (mgal)
NORWAY						
GW 118	Hammerfest	982.6324	"A" .61762	+14.78	.61762	+14.78
WH 1045	Indrefjord	982.6301	"J" .61548	+14.62		
GW 117	Bodo	982.3873	"A" .37265	+14.65	.37264	+14.66
WA 5037	Airport tower	982.3876	"J" .37297	+14.63		
GW Pend	Trondheim Phys, Inst.	982.1614	"A" .14674	+14.66	.14672	+14.68
WA 5040	Vaernes AP	982.1523	"K" .13779	+14.51		
GW 68	Oslo (Geol. Mus.)	981.9272	"A" .91261	+14.59	.91261	+14.59
WA 5038	Fornebu AP	981.9307	"J" .91620	+14.50		
FINLAND						
IGM Sta	Helsinki Univ.	981.9152	"A" .90059	+14.61	.90059	+14.61
WA 5019	Sentula AP	981.9248	"S" .91009	+14.71		
SWEDEN						
Kartverk	Stockholm	981.8465	"A" .83143	+15.07		
WA 5053	Bromma AP	981.8455	"J" .83066	+14.84		

Table III (cont.)

	(1) Woollard and Rose	(2) IGSN 71	1-2 Diff (mgal)	(3) IGSN 71 DMA AC	1-3 Diff (mgal)
DENMARK					
GW 64	Copenhagen	"B" .54319	+14.51		
WA 5004	Kastrup AP	"J" .54275	+14.55		
WA 5059	Kastrup AP	"L" .54226	+14.54		
WEST GERMANY					
GW 63	Bad Harzburg	"A" .16550	+14.80		
GW 63A	Braunshweig Abs.	"C" .25184	+14.96	.25183	+14.97
Abs Pier	Potsdam	"A" .26019	+14.71		
GW 62	Frankfurt	"A" .04632	+14.68		
WA 5028	Airport	"J" .04243	+14.67		
ENGLAND					
GW 67	Teddington	"A" .18178	+14.82	.18177	+14.83
WA 5012	London AP Term 1	"J" .18558	+14.72		
WA 5013	old Term	"M" .18704	+14.66		
Camb.Pend.	Cambridge Univ.			.25394	+14.86
SCOTLAND					
Camb.Pend.	Edinburgh R. Obs.	"A" .56897	+14.93	.56895	+14.95
WA 5047	Prestwick AP	"J" .56351	+14.89		
WA 5046	Prestwick MATS	"K" .56113	+14.67	.56111	+14.69

Table III (cont.)

	(1) Woollard and Rose	(2) IGSN 71	1-2		(3)		1-3	
			Diff (mgal)	IGSN 71	DMA AC	Diff (mgal)	DMA AC	Diff (mgal)
WA 5044	Glasgow Renfew AP	981.6018		"N" .58692		+14.98		
Camb.Pend.	Aberdeen, Marischal	981.6998					.68482	+14.98
IRELAND								
Camb. Pend.	Dublin Dunsink Obs,	981.3891					.37478	+14.32
NETHERLANDS								
Pend.Base	DeBilt. R.N.O.	981.2693					.25456	+14.74
WA 5036	Amsterdam AP	981.2882		"J" .27340		+14.80		
FRANCE								
CW 114	Paris (SEVRES)	980.9409		"A" .92597		+14.93	.92596	+14.94
Gm Base	Paris Obs. "A"	980.9434		"B" .92865		+14.75		
Pend.Base	Paris Obs. pier	980.9432		"E" .92829		+14.91		
WA 5058	Orly AP Term.	980.9160		"N" .90101		+14.99		
WA 5024	Le Bourget AP	980.9502		"J" .93534		+14.86		
SPAIN								
Pend.Base	Madrid, Astro. Obs.	979.9812		"A" .96652		+14.68	.96652	+14.68
Gm Base	Madrid IGC	979.9703		"C" .95561		+14.69		
WA 5049	Barajas AP	979.9988		"J" .98414		+14.64		
WA 5051	Torrejon AFB	980.0072		"M" .99251		+14.69		

Table III (cont.)

		(1) Woollard and Rose	(2) IGSN 71	1-2 Diff (mgal)	(3) IGSN 71 DMA AC	1-3 Diff (mgal)
PORTUGAL						
GW 110	Lisbon IGC	980.0903	"A" .07573	+14.57	.07571	+14.59
WA 5041	Lisbon AP	980.0796	"K" .06512	+14.48		
SWITZERLAND						
Pend.	Zurich Geod. Base Inst.	980.6670	"A" .65213	+14.87	.65212	+14.88
WA 5055	Kloten AP	980.6871	"J" .67218	+14.92		
ITALY						
GW 61	Rome Univ. Physics	980.3639	"A" .34923	+14.67		
Natl Base	Univ. Fac. Ing.	980.3619	"B" .34722	+14.68		
	Roco de Papa Obs.	980.1929	"C" .17843	+14.47		
WA 5033	Ciampino Est AP	980.3489	"J" .33427	+14.63		
WA 5034	Ciampino Ovest AP	980.3478	"M" .33319	+14.61		
WA 5060	Fiumicino Int'l AP	980.3765	"N" .36176	+14.74		
LEBANON						
LeJay Pend.	Beirut Fac. Med.	979.6909	"A" .67625	+14.65	.67624	+14.66
WA 2050	Khalde AP (a)	979.6934	"J" .67864	+14.76		
WA 2051	Khalde AP (b)	979.6922	"K" .67744	+14.76		



Table IV-A  
Comparison of Woollard and Rose Gravimeter Values and IGSN  
71 Values at Pendulum sites and their Excenters in Africa

A - Mid-continent Series

	(1) Woollard and Rose	(2) IGSN 71	1-2 Diff (mgal)	(3) IGSN 71 DMA AC	1-3 Diff (mgal)
CYPRUS					
Camb. Nicosia Pend	979.8492			.83449	+14.71
LIBYA					
GW 60 Tripoli-Wheelus	979.5876	"A" .57272	+14.88	.57273	+14.87
WA 1021 Idris AP	979.5379	"L" .52300	+14.90		
EGYPT					
GW 69 Cairo Helwan Obs	979.2915	"B" .27676	+14.74		
WA 1002 Farouk Int'l AP	979.3160	"L" .30125	+14.75		
ETHIOPIA					
GW 76 Asmara (Kagnew)	977.8194	"A" .80545	+13.95	.80545	+13.95
WA 1005 Mun. AP	977.8224	"J" .80826	+14.14		
SUDAN					
GW 70 Khartoum Univ	978.3034	"B" .28867	+14.73		
GW 70A Univ. pend. site	978.3033	"A" .28864	+14.66		
WA 1045 Airport Term.	978.3034	"L" .28865	+14.75	.28863	+14.77

Table IV-A (cont.)

		(1) Woodlard and Rose	(2) IGSN 71	1-2 Diff (mgal)	(3) IGSN 71 DMA AC	1-3 Diff (mgal)
KENYA						
GW 71	Nairobi	977.5403	"A" .52607	+14.23	.52607	+14.23
Camb P.	Bullard (1)	977.5279	"C" .51375	+14.15		
WA 1014	Eastleigh AP	977.5430	"J" .52877	+14.23		
WA 1015	West Civil AP	977.5357	"K" .52151	+14.19		
ZAMBIA						
GW 75	Lusaka AP	978.0536	"A" .03929	+14.31		
RHODESIA						
Camb P.	Salisbury	978.1481	"A" .13365	+14.45	.13363	+14.47
WA 1043	Belvedere AP	978.1484	"J" .13414	+14.26		
SOUTH AFRICA						
GW 73	Johannesburg BPI	978.5495	"A" .53546	+14.04	.53547	+14.03
WA 106?	Jon Smuts AP	978.5503	"K" .53610	+14.20		
Camb P	Pretoria Mus.	978.6296	"A" .61530	+14.30		
GW 74	Capetown, Mowbroy	979.6473	"A" .63271	+14.59	.63271	+14.59
Camb P	Royal Obs.	979.6535	"B" .63893	+14.57		
WA 1051	Malon AP	979.6462	"J" .63145	+14.75		
WA 1056	Wingfield AP	979.6494	"L" .63484	+14.56		

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PROGRESS IN THE GLOBAL STANDARDIZATION OF GRAVITY: AN ANALYSIS --ETC(U)

DEC 80 G P WOOLLARD, V M GODLEY

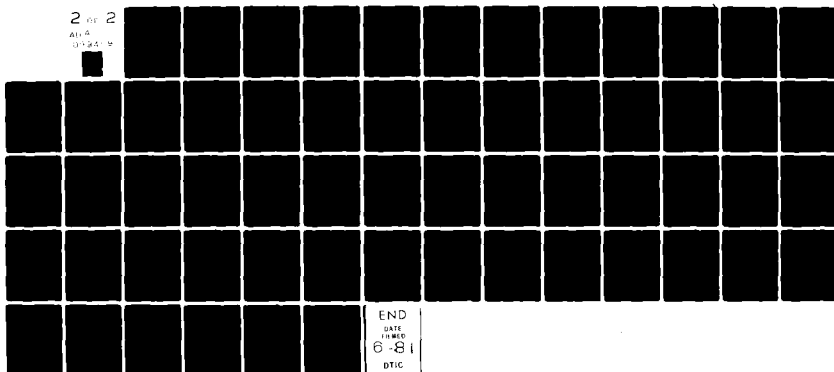
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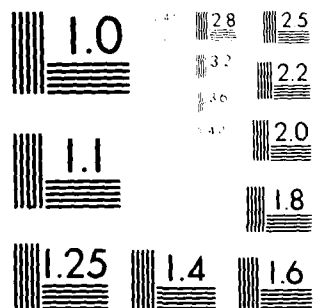
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Table IV-B  
Comparison of Woollard and Rose Gravimeter Values and IGSN  
71 Values at Pendulum sites and their Excenters in Africa

B - West Coast Series

	(1) Woollard and Rose	(2) IGSN 71	1-2 Diff (mgal)	(3) IGSN 71 DMA AC	1-3 Diff (mgal)
SENEGAL					
GW 111	Dakar. Mbour	978.3852	"B" .37039	+14.81	
WA 1010	Yof AP	978.4772	"J" .46242	+14.78	
GHANA					
GW 112	Accra Univ.	978.1059	"A" .09141	+14.49	
WA 1012	Airport	978.1153	"J" .10052	+14.78	
ZAIRE (Congo)					
GW 113	Kinshasa (Leopoldville)	977.9146	"A" .89982	+14.78	+14.76
WA 1037	Int'l AP	977.9518	"J" .93713	+14.67	
WA 1038	Ndjili AP	977.9429	"M" .92820	+14.70	
SOUTH WEST AFRICA					
Camb P	Windhoek	978.3205			
WA 1022	AP Traffic Contr.	978.3210		.30629	+14.71
Camb P	Tsumeb	978.2212			
WA 1070	Airport	978.2209		.20619	+14.71

Table V

## Comparison of Woollard and Rose Gravimeter Values and IGSN 71

## Values at Pendulum sites and their Excenters

## Pacific-Australian Series

		(1) Woollard and Rose	(2) IGSN 71	1-2 Diff (mgal)	(3) IGSN 71 DMA AC	1-3 Diff (mgal)
HAWAII						
GW 55	Honolulu, Bishop Mus.	978.9530	"B" .93835	+14.65	.93836	+14.64
Pend	Univ. Inst. Geophys.	978.9593	"A" .94490	+14.40		
WA 443	Hickam AFB	978.9337	"J" .91914	+14.56		
WA 444	Old Int'l. AP	978.9325	"S" .91810	+14.40		
	New Int'l. AP	978.9335	"Q" .91893	+14.57		
	Inter Is. AP	978.9330	"R" .91843	+14.57		
JAPAN						
GW 103	Sapporo, Hokkaido	980.4406	"B" .42735	+13.25		
WA 2030	Chitose AP	980.4405	"J" .42734	+13.16		
GW 57	Tokyo Univ. ERI	979.8016	"A" .78722	+14.38		
WA 2037	Haneda AP	979.7736	"L" .75916	+14.44		
Pend Base	Kyoto Univ.	979.7216	"A" .70727	+14.33	.70729	+14.31
GW 100	Kadena, Okinawa	979.1265	"A" .11222	+14.28		
WA 2057	Kadena MATS	979.1343	"J" .11992	+14.38		
PHILIPPINES						
GW 58	Manila, Clark AFB	978.3969	"A" .38230	+14.60		
WA 2061	Clark MATS	978.3965	"J" .38183	+14.67		
WA 2062	Manila Int'l. AP	978.3767	"K" .36192	+14.78		

Table V (cont.)

		(1) Woollard and Rose	(2) IGSN 71	1-2 Diff (mgal)	(3) IGSN 71 DMA AC	1-3 Diff (mgal)
HONG KONG						
GW 101	US Consulate	978.7677	"A" .75231	+15.39		
WA 2008	Kai-Tak AP	978.7730	"J" .75766	+15.34		
VIETNAM						
Lejay Pend.	Saigon	978.2285				
WA 2081	Tan San Nhut AP	978.2300	"J" .21509	+14.91	.21509	+14.91
SINGAPORE						
GW 102	Univ. Malaya	978.0815	"A" .06668	+14.82	.06668	+14.82
Pend. Base	Raffles Mus.	978.0809	"B" .06604	+14.86		
WA 2071	Changi Crk. RAFB	978.0801	"E" .06521	+14.89		
WA 2072	Kallang AP	978.0817	"J" .06681	+14.89		
WA 2073	Paya Lebar AP	978.0804	"L" .06561	+14.79		
AUSTRALIA						
NORTHERN TERRITORY						
GW 88	Darwin (BMR Bldg)	978.3140	"A" .29955	+14.45	.29955	+14.45
WA 3058	RAF Officers Club	978.3164	"B" .30192	+14.48		
WA 3014	Airport	978.3154	"J" .30093	+14.47		
WA 3013	Daly Waters BMRP	978.3892			.37487	+14.33

Table V (cont.)

	(1) Woollard and Rose	(2) IGSN 71	1-2 Diff (mgal)	(3) IGSN 71 DMA AC	1-3 Diff (mgal)
QUEENSLAND					
GW 87	Cairns	978.5006	"A" .48624		
GW 86	Townsville RAF	978.6247	"B" .61043		
WA 3043	Airport	978.6240	"C" .60966	.60969	+14.31
GW 85	Brisbane Univ.	979.1695	"B" .15516		
GW 85A	Seismic vault	979.1701	"A" .15593		
WA 3004	Eagle Farm AP	979.1599	"J" .14557		
WA 3067	Archer AP	979.1683	"K" .15411		
BMR P	Rockhampton Jail	978.8707	"A" .85606	.85606	+14.64
WA 3038	Airport	978.8738	"J" .85935		
WA 3027	Maryborough BMR Pend.	979.0219	"A" .00732		
NEW SOUTH WALES					
GW 84	Sydney (N.S.L.)	979.6863	"A" .67186	.67185	+14.45
WA 3043	Kingsford-Smith AP	979.6993	"J" .68480		
WA 3041	Rose Bay AP	979.6965	"L" .68198		
VICTORIA					
GW 38	Melbourne BMR	979.9797	"A" .96518	.96516	+14.54
WA 3028	Essendon AP	979.9628	"J" .94821		
BMR Pend.	Kallista Forest Ranger Sta.	979.9100	"S" .89538		



Table V (cont.)

		(1)	(2)	1-2	(3)	1-3
		Woollard and Rose	IGSN 71	Diff (mgal)	IGSN 71 DMA AC	Diff (mgal)
SOUTH AUSTRALIA						
BMR Pend.	Adelaide Univ.	979.7243			.70920	+15.10
WESTERN AUSTRALIA						
BMR P	Perth Univ.	979.3958	"A" .38086	+14.94	.38066	+15.14
WA 3035	Airport	979.4011	"K" .38632	+14.78		
WA 3015	Derby BMR Pend.	978.5207			.50569	+15.01
WA 3036	Port Hedland	978.6466			.63150	+15.17
NEW ZEALAND						
NORTH ISLAND						
GW 81	Wellington (L. Hutt)	980.2934	"C" .27909	+14.31		
Pend Base	Wellington DSIR	980.2656	"A" .25100	+14.60	.25099	+14.61
WA 3058	Rongotai AP	980.3064	"K" .29201	+14.39		
DSIR	Auckland WM Mus.	979.9487	"B" .93411	+14.59		
WA 3047	Whenuapai AP	979.9408	"C" .92604	+14.76		
NEW ZEALAND						
SOUTH ISLAND						
GW 79	Christchurch	980.5089	"A" .49429	+14.61	.49429	+14.61
WA 3103	Int'l Airport	980.4962	"L" .48159	+14.61		
WA 3049	Harewood AP	980.4962	"K" .48147	+14.73		
GW 89	Dunedin, Otago Univ.	980.7424	"A" .72753	+14.87	.72751	+14.89
WA 3051	Taieri Airport	980.7366	"C" .72175	+14.85		

Table V (cont.)

	(1) Woollard and Rose	(2) IGSN 71	1-2 Diff (mgal)	(3) IGSN 71 DMA AC	1-3 Diff (mgal)
ANTARCTICA					
GW 82	McMurdo	"A"	.97683	+15.07	
WA 9013	Scott Base	"L"	.97318	+15.12	
GW 119	Mirny			.39059	+14.61
GW 120	Mawson			.46719	+14.61

Table VI

## Comparison of Woollard and Rose Gravimeter Values and IGSN 71

## Values at Pendulum sites and their Excenters

## India and Iceland

		(1) Woollard and Rose	(2) IGSN 71	1-2 Diff/ (mgal)	(3) IGSN 71 DMA AC	1-3 Diff/ (mgal)
INDIA						
GW 59	New Delhi	979.1363	"A" .12155	+14.75		
WA 2019	Palam AP	979.1341	"J" .11938	+14.72		
WA 2020	Willington AP	979.1379	"K" .12316	+14.74		
Natl.Gr. Base	Dehra Dun	979.0636	"A" .04909	+14.51	.04908	+14.52
SI Pend.	Bangalore	978.0294	"A" .01389	+15.51	.01389	+15.51
WA 2011	Bangalore AP	978.0387	"J" .02314	+15.56		
SI Pend.	Madras Metr. Cntr.	978.2818	"A" .26655	+15.25	.26655	+15.25
WA 2018	St. Thomas Mt. AP	978.2804	"J" .26516	+15.24		
CEYLON						
SI Pend.	Colombo Metr. Obs.	978.1328	"B" .11724	+15.56		
Mejnesz Pend.	French Consulate	978.1403	"C" .12454	+15.76	.12454	+15.76
WA 2004	Ratmalana AP	978.1323	"J" .11690	+15.40		
ICELAND						
IGM Base	Reykjavik Univ.	982.2800	"A" .26496	+15.04		
WH 1035	Long Pier	982.2813	"J" .26634	+14.96		
WA 7006	Keflavik AP	982.2744	"K" .25943	+14.97		
WA 7007	Reykjavik AP	982.2784	"L" .26333	+15.07		

## Appendix II

Tables of Differences in Woollard and Rose  
(1963) Gravimeter Values and IGSN Values on an Areal Basis

Sites with designations "A", "B", "C", "J", etc. are compared against the IGSN 71 values of Morelli et al. (1974). At all other sites the comparison is with the IGSN 71 values derived by the U.S. Defense Mapping Agency Aerospace Center (unpublished). Values followed by \* are DMAC values.

The site code numbering system is that given in SEG special publication International Gravity Measurements (Woollard and Rose, 1963). CW - Pendulum observation sites established by Woollard and Rose; WA - Airports; WH - Harbor sites; others as indicated.

Page

A. Sites in North America

101-116

1. Alaska (53 sites)
2. Canada (52 sites)
3. United States (167 sites)
4. Mexico (29 sites)
5. Central America and West Indies (27 sites)

B. Sites in South America

117-123

- |                         |                        |
|-------------------------|------------------------|
| 1. Argentina (21 sites) | French Guiana (1 site) |
| 2. Bolivia (17 sites)   | Guyana (3 sites)       |
| 3. Brazil (81 sites)    | Paraguay (1 site)      |
| 4. Chile (17 sites)     | Peru (8 sites)         |
| 5. Colombia (14 sites)  | Surinam (1 site)       |
| 6. Ecuador (7 sites)    | Uruguay (1 site)       |
|                         | Venezuela (13 sites)   |

## C. Sites In Europe

124-127

- |                          |                               |
|--------------------------|-------------------------------|
| 1. Cyprus (1 site)       | 8. Norway (9 sites)           |
| 2. Denmark (3 sites)     | 9. Portugal (2 sites)         |
| 3. Eire (1 site)         | 10. Spain (4 sites)           |
| 4. Finland (2 sites)     | 11. Sweden (2 sites)          |
| 5. France (7 sites)      | 12. Switzerland (3 sites)     |
| 6. Italy (7 sites)       | 13. United Kingdom (10 sites) |
| 7. Netherlands (2 sites) | 14. West Germany (6 sites)    |

## D. Sites in Africa

128-131

- |                          |                                |
|--------------------------|--------------------------------|
| 1. Algeria (1 site)      | 12. Nigeria (1 site)           |
| 2. Egypt ( 5 sites)      | 13. Rhodesia (4 sites)         |
| 3. Ethiopia (6 sites)    | 14. Senegal (2 sites)          |
| 4. Gambia (1 site)       | 15. Somali (1 site)            |
| 5. Ghana (2 sites)       | 16. South Africa (11 sites)    |
| 6. Guinea (1 site)       | 17. Southwest Africa (3 sites) |
| 7. Kenya (4 sites)       | 18. Sudan (4 sites)            |
| 8. Libya (4 sites)       | 19. Tanzania (5 sites)         |
| 9. Malagasy (1 site)     | 20. Tunisia (2 sites)          |
| 10. Morocco (2 sites)    | 21. Uganda (1 site)            |
| 11. Mozambique (2 sites) | 22. Zaire (3 sites)            |
|                          | 23. Zambia (4 sites)           |

## E. Sites in Southwest and South Asia

132-134

- |                     |                             |
|---------------------|-----------------------------|
| 1. Bahrein (1 site) | 8. Pakistan (1 site)        |
| 2. Ceylon (3 sites) | 9. Qater (1 site)           |
| 3. India (13 sites) | 10. Saudi Arabia (4 sites)  |
| 4. Iran (1 site)    | 11. Trucial States (1 site) |
| 5. Iraq (4 sites)   | 12. Turkey (2 sites)        |

## Page

## E. Sites in Southwest and South Asia (continued)

- 6. Kuwait (1 site)                      13. Yemen (1 site)
- 7. Lebanon (3 sites)

## F. Sites in Southeast and East Asia

135-138

Southeast Asia

- 1. Cambodia (1 site)
- 2. Federation of Malaysia (5 sites)
- 3. Hong Kong (3 sites)
- 4. Indonesia (1 site)
- 5. New Caledonia (1 site)
- 6. New Guinea area and Bismark archipelago (15 sites)
- 7. Philippines (4 sites)
- 8. Singapore (5 sites)
- 9. Solomon Islands (2 sites)
- 10. Taiwan (1 site)
- 11. Thailand (1 site)
- 12. Vietnam (4 sites)

East Asia

- 1. Japan ( 9 sites)
- 2. South Korea (3 sites)
- 3. Okinawa (2 sites)

## G. Sites in Australia and New Zealand

139-140

- 1. Australia (37 sites)
- 2. New Zealand (11 sites)

## H. Sites on Oceanic Islands

141-143

Atlantic Area

1. Ascension (1 site)
2. Azores (2 sites)
3. Bermuda (2 sites)
4. Greenland (2 sites)
5. Iceland (4 sites)

Pacific Area

- |                                |                               |
|--------------------------------|-------------------------------|
| 6. Fiji (2 sites)              | 12. Samoa (1 site)            |
| 7. Guam (1 site)               | 13. Society Islands (2 sites) |
| 8. Hawaii (6 sites)            | 14. Tonga (1 site)            |
| 9. Line Is. (1 site)           | 15. Wake (1 site)             |
| 10. New Caledonia (1 site)     | 16. Wallis (1 site)           |
| 11. Phoenix Islands (16 sites) |                               |

Indian Ocean Area

17. Cocos (1 site)
18. Heard (1 site)
19. Keruelan (1 site)
20. Maritius (1 site)



Table A-1  
Comparison of Woollard and Rose (1963)  
Gravimeter Values with IGSN 71 Values  
on an Areal Basis in Alaska

		Woollard and Rose	IGSN 71	Diff
WA 321	Adak 'J'	981.4420	.427 64	14.36
WA 322	Allaket	982.3583	.344 05*	14.25
WA 323	Anchorage	981.9204	.905 86*	14.54
			.905 82*	14.58
USC Pend	Anchorage 'A'	981.9400	.925 19	14.81
WA 474	Elmendorf AFB 'J'	981.9382	.923 56	14.64
WA 324	Attu Is.	981.5274	.513 28*	14.12
WA 325	Barter Is. 'J'	982.5954	.581 56	13.84
			.581 55*	13.85
WA 327	Beaver	982.3315	.316 40*	15.10
WA 329	Bettles	982.3842	.369 45*	14.75
WA 331	Cape Lisburne	982.5304	.516 59*	13.81
WA 332	Cape Newenham	981.8247	.809 97*	14.73
WA 337	Chitina	981.9492	.929 47*	10.73 Site?
WA 338	Circle	982.3049	.290 09*	14.81
WA 339	Cordova	981.9579	.934 09*	14.81
WA 340	Demarcation Pt.	982.5672	.552 93*	14.27
WA 341	Dillingham	981.8658	.854 74*	11.06 Site?
WA 342	Dutch Harbor	981.5530	.538 58*	14.42
GW 6	Fairbanks "A"	982.2462	.231 71	14.49
			.231 70*	14.50
GW 27	Fairbanks "B"	982.2444	.229 91	14.49
Abs	Fairbanks "E"	982.2495	.235 00	14.50
WA 279	Fairbanks "J"	982.2464	.231 97	14.43
WA 349	Flat	982.0936	.078 91*	14.69
WA 351	Fort Yukon	982.3580	.343 40*	14.60
WA 355	Gulkana	981.9314	.916 95*	14.45
WA 357	Homer	981.8824	.868 49*	13.91
WA 358	Hughes	982.3341	.319 45*	14.65

Table A-1

## Alaska (cont.)

		Woollard and Rose	IGSN 71	Diff	
WA 360	Huslia	982.3213	.307 90*	13.40	Site?
WA 361	Iliamna	981.9030	.888 39*	14.61	
WA 363	Juneau	981.7680	.753 64*	14.36	
WA 364	Kenai	981.8378	.822 78*	15.02	
WA 365	King Salmon	981.8426	.827 99*	14.61	
WA 368	Kotzebue	982.4141	.339 73*	14.37	
WA 369	Koyuk	982.2929	.278 51*	14.39	
WA 370	Koyukuk	982.2801	.266 34*	13.76	
WA 372	Livengood	982.2725	.258 23*	14.27	
WA 375	McGrath	982.1284	.113 59*	14.81	
WA 377	Munchumina	982.1545	.139 98*	14.52	
WA 380	Nome	982.2749	.259 20*	15.70	Site?
WA 382	Palmer	981.9816	.967 99*	13.61	
GW 105	Point Barrow "A"	982.6996	.685 18	14.42	
			.685 17*	14.43	
WA 280	Point Barrow "K"	982.6998	.685 21	14.59	
WA 385	Ruby	982.2376	.252 55*	15.05	
WA 387	Shemva	981.5088	.492 08*	16.72	Site?
WA 388	Skagway	981.7736	.758 80*	14.80	
WA 390	Stevens Village	982.3244	.309 06*	15.34	
WA 393	Tanana	982.2782	.263 70*	14.50	
WA 395	Teller	982.3119	.297 15*	14.75	
WA 396	Tin City	982.3141	.299 63*	14.47	
WA 281	Umiat	982.5444	.500 65*	14.75	
WA 397	Umnak Is.	981.5176	.502 73*	14.87	
WA 398	Unalakleet	982.2178	.202 83*	14.97	
WA 404	Yakataga	981.9937	.801 54*	12.16	Site
WA 405	Yahutat	981.8371	.822 49*	14.61	

Table A-2  
Comparison of Woollard and Rose Gravimeter Values  
and IGSN 71 Values on an Areal Basis in Canada

		Woollard and Rose	IGSN 71	Diff
ALBERTA				
GW 32	Calgary "A"	980.8281	813 55	14.55
WA 180	Calgary "J"	980.8288	814 25	14.55
GW 25	Edmonton "B"	981.1678	153 16	14.64
			153 09*	14.71
GW 5	Edmonton "C"	981.1672	152 79	14.41
WA 181	Edmonton "K"	981.1729	158 38	14.52
WA 282	RCAF NAMA0 "M"	981.1803	165 84	14.46
Camb	Grande Prairie "A"	981.3180	303 22	14.78
			303 20*	14.80
GW 10	Grande Prairie "B"	981.3175	302 85	14.65
WA 183	Grande Prairie "J"	981.3158	300 99	14.81
GW 33	Lethbridge "A"	981.7589	744 62	14.28
			744 61*	14.29
GW 12	Lethbridge "C"	981.7584	744 18	14.22
WA 184	Lethbridge "J"	981.7538	739 15	14.65
BRITISH COLOMBIA				
Camb	Fort Nelson "A"	981.6828	668 17*	14.63
WA 182	Fort Nelson "J"	981.6929	678 39	14.51
GW 27	Fort St. John "A"	981.4059	391 21	14.69
WA 284	Fort St. John "J"	981.4055	390 78	14.72
			390 79*	14.71
WA 285	Liard River	981.7041	689 47*	14.63
WA 286	Prince George	981.1772	162 14*	15.06
WA 288	Sikanni Chief	981.3941	379 46*	14.64
Dom Obs	Vancouver "A"	980.9352	920 68	14.52
			920 68*	14.52
WA 186	Vancouver "J"	980.9299	915 41	14.49

Table A-2 (cont.)

## Canada (cont.)

		Woollard and Rose	IGSN 71	Diff
LABRADOR				
WA 291	Goose Bay "J"	981.3078	292 81	14.99
	"K"		293 24	14.56
MANITOBA				
WA 292	Churchill	981.7675	752 87*	14.63
WA 80	Winnipeg "J"	980.9924	977 56	14.84
NEWFOUNDLAND				
WA 294	Argentia	980.8539	840 15*	13.75 site?
WA 297	St. Johns	980.8369	822 25*	14.65
WA 298	Stephenville	980.9318	916 77*	15.03
NORTHWEST TERRITORY				
WA 301	Aklavik	982.4902	475 59*	14.61
WA 302	Cape Parry	982.6220	607 40*	14.60
	Cornwallis Is.			
WA 303	Resolute Bay	982.8624	848 74	13.66
			848 73*	13.67
	Ellesmere Land			
WA 304	Alert	983.1417	117 96*	23.74 site?
WA 305	Eureka	983.0275	014 09	13.41
			014 06*	13.44
	Ellef Rignes Is.			
WA 306	Isachsen	983.0597	045 10*	14.60
	Prince Patrick Is.			
WA 307	Mould Bay	982.9333	.918 70*	14.60
WA 308	Yellowknife	982.0245	.009 88*	14.62
	Victoria Island			
WA 309	Cambridge Bay	982.5182	.503 59*	14.61
ONTARIO				
Dom Obs	Ottawa "A"	980.6208	606 14	14.66
GW 53	Ottawa "B"	980.6217	607 10	14.60
			607 07*	14.63
WA 310	Ottawa "L"	980.6187	604 14	14.56
WA 79	Toronto	980.4298	415 09	14.71
			415 09*	14.71

Table A-2 (cont.)

## Canada (cont.)

		Woollard and Rose	IGSN 71	Diff
QUEBEC				
WA 77	Montreal "N"	980.6437	629 24	14.46
WA 185	Quebec	980.7405	725 92*	14.58
YUKON				
WA 311	Burwash	981.7543	739 67*	14.63
WA 312	Dawson	982.5223	507 69*	14.61
WA 313	Shingle Point	982.5223	507 69*	14.61
WA 314	Stokes Point	982.5702	555 59*	14.61
WA 315	Teslin Lake	981.7270	712 37*	14.63
Dom Obs	Watson Lake "A"	981.7150	700 39	14.61
WA 476	Watson Lake "J"	981.7143	699 98	14.32
GW 26	Whitehorse "B"	981.7486	734 25	14.35
WA 188	Whitehorse "J"	981.7487	734 25	14.45

Table A-3

## Comparison of Woollard and Rose Gravimeter Values and IGSN 71

## Values on an Areal basis in the United States

		Woollard and Rose	IGSN 71	Diff
ALABAMA				
WA 82	Mobile	979.3396	324 69*	14.91
ARIZONA				
WA 194	Douglas	979.0576	042 90*	14.70
WA 195	Flagstaff	979.1427	128 35*	14.35
WA 196	Nogales	979.0701	055 24*	14.86
WA 2	Phoenix	979.4918	476 83*	14.97
WA 197	Prescott	979.2406	226 39*	14.21
WA 3	Tucson	979.2277	213 01*	14.69
WA 198	Winslow	979.2777	263 55*	14.15
ARKANSAS				
WA 4	Little Rock "J"	979.7245	709 40	15.10
CALIFORNIA			709 40*	15.10
WA 202	Fairfield	979.9898	975 38*	14.42
WA 83	Los Angeles	979.5946	580 00*	14.60
WA 207	Red Bluff	980.1046	090 06*	14.54
WA 85	San Diego "J"	979.5369	522 36	14.54
			522 38*	14.52
WA 453	San Diego "K"	979.5336	518 54	15.06
GW 54	San Francisco "A"	979.9867	972 13	14.57
			972 37*	14.33
WA 86	San Francisco "K"	979.9883	973 75	14.55
WA 87	San Francisco "J"	979.9885	973 81	14.69
COLORADO				
GW 39	Denver "B"	979.6117	597 10	14.60
X cntr	Denver "D"	979.6114	596 53	14.87
WA 89	Denver "J"	979.6333	618 97	14.33
WA 90	Denver "K"	979.6327	618 48	14.22
CONNECTICUT				
WU 8	New Haven	980.3163	301 50*	14.80

Table A-3 (cont.)

## United States (cont.)

		Woollard and Rose	IGSN 71	Diff
DISTRICT OF COLUMBIA				
US 337	Commerce Pier "A"	980.1188	.104 29	-14.51
U337A	Commerce 14th St. "C"	980.1182	.103.63	-14.57
GW 2	CIW Dept. Terr. Mag. "D"	980.1006	.086 05	-14.55
Old NBS	NBS Abs Conn Av. "E"	980.0995	.084 86	-14.64
WA 493	Natl. Airport "K"	980.1089	.094 40	-14.50
FLORIDA				
WA 484	Daytona Beach "J"	979.2771	.262 50	-14.60
WA 217	Jacksonville "J"	979.3856	.370 97	-14.63
GW 116	Key West "A"	978.9692	.954 46	-14.54
WH 39	Key West NB "J"	978.9686	.954 07	-14.53
GW 115	Miami Mar. Lab. "A"	979.0356	.020 95	-14.65
WH 3	Miami Port "B"	979.0356	.020 96	-14.64
WA 278	Miami Intl. AP "J"	979.0528	.038 29	-14.51
WA 11	Miami EAL "L"	979.0543	.039 57	-14.73
WA 13	Orlando AP "J"	979.2187	.204 09	-14.61
WA 464	Orlando McCoy AFB "L"	979.2004	.185 84	-14.56
WA 461	Pompano Beach "N"	979.0864	.071 58	-14.82
WA 462	St. Augustine "O"	979.3418	.327 21	-14.59
WA 16	Tampa "J"	979.2044	.189 59	-14.81
			.189 53*	-14.87
WA 460	Vero Beach "J"	979.1737	.159 04	-14.66
WA 17	West Palm Beach "J"	979.1333	.118 70	-14.60
GEORGIA				
	Atlanta, Emory U. "A"	979.5380	.523 57	-14.43
WA 470	Atlanta AP "J"	979.5206	.506 31	-14.29
WA 469	Atlanta AP "K"	979.5211	.506.90	-14.20
WA 18	Brunswick "J"	979.4494	.434 74	-14.66
WA 19	Columbus	979.5125	.507 31*	-15.19 Site?
WA 20	Macon	979.5321	.517 48*	-14.62
WA 99	Savannah "J"	979.4977	.483 08	-14.62
IDAHO				
WA 21	Boise "J"	980.2082	.193 64	-14.56

Table A-3(cont.)

United States (cont.)

		Woollard and Rose	IGSN 71	Diff
ILLINOIS				
GW 23	Chicago "A"	980.2873	.272 62	-14.68
WA 101	Midway "J"	980.2864	.271 79	-14.61
WA 23	Springfield	980.0821	.067 43*	-14.67
INDIANA				
WA 103	West Lafayette	980.1469	.132 40*	-14.50
IOWA				
WA 220	Boone	980.3226	.307 59*	-15.01
W 24	Cedar Rapids	980.2519	.237 35*	-14.55
WA 221	Cleremont	980.3787	.363 93*	-14.77
WA 222	Davenport	980.2521	.236 60*	-15.50 site?
WA 25	Des Moines	980.1984	.184 41*	-13.99 site?
WA 228	Sioux City "J"	980.3073	.292 98	-14.32
KANSAS				
GW 52	Beloit	979.9981	.983 59*	-14.51
WA 106	Wichita "J"	979.8408	.826 26	-14.54
KENTUCKY				
WA 107	Lexington	979.8988	.884 12*	-14.68
WA 26	Louisville "J"	979.9585	.943 67	-14.83
LOUISIANA				
WA 108	Baton Rouge	979.3637	.349 01*	-14.69
WA 230	Lake Charles	979.3324	.317 71*	-14.69
WA 110	New Orleans "J"	979.3298	.314 94	-14.86
MAINE				
WA 231	Augusta	980.5372	.522 54*	-14.66
WA 457	Bangor "J"	980.5912	.576 45	-14.75
WA 458	Caribou "J"	980.7322	.717 49	-14.71
WA 232	Greenville	980.5895	.574 84*	-14.66
MARYLAND				
WA 112	Baltimore "M"	980.1034	.088 67	-14.73
MASSACHUSETTS				
WA 114	Boston "O"	980.4036	.389 24	-14.36
WA 472	Hyannis	980.3400	.325 41*	-14.59



Table A-3(cont.)

United States (cont.)

		Woollard and Rose	IGSN 71	Diff
GW 77A	Woods Hole BM	980.3271	.312 49*	-14.61
MICHIGAN				
	Detroit			
WA 116	"K" Willow Run AP	980.3188	.304 08	-14.72
WA 496	"L" Metropolitan AP	980.3190	.304 46	-14.54
MINNESOTA				
WA 118	Minneapolis "K"	980.5950	.580 92	-14.08 Site?
MISSOURI				
WA 120	Kansas City "J"	979.9998	.985 46	-14.34
WA 121	St. Louis "J"	980.0042	.989 52	-14.68
MONTANA				
GW 25	Billings "A"	980.3710	.356 37	-14.63
WA 122	Billings AP "K"	980.3717	.357 37	-14.33
WA 123	Butte	980.1744	.159 88*	-14.52
GW 34	Cutbank "B"	980.6085	.593 83	-14.67
WA 242	Glendive	980.6371	.622 44*	-14.66
GW 4	Great Falls "A"	980.5269	.512 30	-14.60
WA 482	Great Falls "J"	980.5137	.499 11	-14.59
WA 243	Malmstrom AFB "K"	980.5231	.514 52	-14.58
WA 31	Helena	980.3778	.363 50*	-14.30
WA 32	Kalispell	980.5818	.567 39*	-14.41
WA 244	Miles City	980.5230	.508 55*	-14.45
WA 127	Missoula	980.4440	.429 45*	-14.55
WA 245	Stanford	980.4369	.422 55*	-14.35
NEVADA				
WA 39	Ely	979.4946	.480 08*	-14.52
WA 450	Indian Springs	979.5560	.541 16*	-14.84 Site
WA 128	Las Vegas "J"	979.6049	.590 37	-14.53
WA 40	Tonopah	979.4767	.462 25*	-14.45
NEW JERSEY				
WA 248	Newark	980.2415	.226 89*	-14.61
GW 78	Princeton "A"	980.1783	.163 73	-14.57
GW 78A	Princeton Univ "B"	980.1776	.163 06	-14.54

Table A-3(cont.)

United States (cont.)		Woollard and Rose	IGSN 71	Diff
WA 42	McGuire AFB "J"	980.2128	.198 36	-14.44
NEW MEXICO				
WA 130	Albuquerque "K"	980.2081	.193 51	-14.59
NEW YORK				
	New York City			
WA 252	Idlewild "R"	980.2273	.212 59	-14.71
WA 133	Kennedy "K"	980.2261	.211 35	-14.75
WA 132	La Guardia "S"	980.2825	.267 77	-14.73
WA 14	Navy Yard "Q"	980.2721	.257 36	-14.74
WA 134	Syracuse "K"	980.3968	.382 08	-14.72
NORTH CAROLINA				
WA 44	Charlotte "J"	979.7283	.713 43	-14.87 site?
WA 46	New Bern	979.7286	.714 16*	-14.44
NORTH DAKOTA				
WA 49	Bismarck "J"	980.6274	.612 75	-14.65
WA 50	Fargo "J"	980.7270	.712 66	-14.34
WA 51	Jamestown	980.6540	.639 34*	-14.66
WA 447	Pembina	980.9166	.902 48*	-14.12 site?
OHIO				
WA 137	Cleveland	980.2322	.217 56*	-14.64
WA 22	Columbus (Univ) "C"	980.0961	.081 40	-14.70
WA 138	Columbus "J"	980.0791	.064 21	-14.89 site?
OKLAHOMA				
GW 52	Tulsa Univ.	979.7661	.751 46*	-14.64
OREGON				
WA 140	Eugene	980.5148	.500 23*	-14.57
WA 55	Pendleton	980.5117	.496 76*	-14.94
WA 142	Portland "J"	980.6483	.633 62	-14.68
WA 56	Salem	980.5837	.569 03*	-14.67
PENNSYLVANIA				
WA 145	Pittsburgh "J"	980.0993	.084 46	-14.84
SOUTH CAROLINA				
GW 90	Charleston "A"	979.5509	.536 35	-14.55

Table A-3 (cont.)

## United States (cont.)

		Woollard and Rose	IGSN 71	Diff
WA 449	Charleston AP "J"	979.5667	.552 16	-14.54
WA 148	Charleston AP "K"	979.5668	.552 27	-14.53
WA 147	Charleston MATS	979.5675	.552 98	-14.52
WA 57	Florence "J"	979.6851	.670 34	-14.76
SOUTH DAKOTA				
WA 59	Aberden	980.5438	.529 19*	-14.61
U 1200	Huron (BM)	980.4530	.438 59*	-14.41
WA 262	Sioux Falls "J"	980.3616	.347 49	-14.11
WA 64	Spearfish	980.2521	.237 98*	-14.12
TENNESSEE				
WA 149	Chatanooga	979.6505	.635 82*	-14.68
TEXAS				
GW 50	Amarillo "A"	979.4235	.409 11	-14.39
WA 67	Amarillo AP "J"	979.4234	.408 87	-14.53
WA 263	Beaumont	979.3149	.300 21*	-14.69
WA 264	Childress	979.4881	.473 95*	-14.15
WA 266	Dalhart	979.4402	.425 51*	-14.69
WA 154	Dallas "J"	979.5131	.498 41	-14.69
GW 18	Houston "A"	979.2983	.283 72	-14.58
WA 159	Houston "J"	979.2932	.278 66	-14.64
GW 18-A	Houston "B"	979.2983	.283 72	-14.58
WA 160	Laredo "J"	979.0792	.064 61	-14.59
WA 68	Lubbock "J"	979.3228	.308 36	-14.44
GW 40	San Antonio "A"	979.1975	.182 73	-14.77
WA 162	San Antonio "J"	979.1976	.182 86	-14.74
WA 161	San Antonio "L"	979.1973	.182 57	-14.73
UTAH				
WA 209	Ogden, Hill AFB "J"	979.8005	.786 08	-14.42
WA 163	Salt Lake City "L"	979.8070	.782 44	-14.56
WA 164	Vernal	979.6686	.653 80*	-14.80
VERMONT				
WA 165	Burlington	980.5181	.503 73*	-14.37
VIRGINIA				
WA 73	Richmond "J"	979.9534	.938 66	-14.74

Table A-3 (cont.)

United States (cont.)

		Woollard and Rose	IGSN 71	Diff
WA 168	Roanoke	979.8076	.793 11	-14.49
WASHINGTON				
GW 104	Seattle "A"	980.7388	.724 34	-14.46
WA 170	Seattle AP "K"	980.7765	.762 02	-14.48
WA 173	Spokane "K"	980.6463	.631 78	-14.52
WEST VIRGINIA				
WA 174	Charleston	979.9259	.911 29*	-14.61
WA 274	Huntington	979.9519	.937 65*	-13.85 site?
WISCONSIN				
GW 3	Madison "A"	980.3689	.354 22	-14.68
WA 76	Madison AP "J"	980.3725	.357 82	-14.68
WYOMING				
GW 37	Casper Pend.	979.9558	.941 33*	-14.47
WA 177	Casper AP "J"	979.9562	.941 59	-14.61
GW 38	Cheyenne "A"	979.7006	.686 18	-14.42
GW 37	Cheyenne "B"	979.7008	.686 30	-14.50
WA 178	Cheyenne AP "J"	979.7008	.686 23	-14.57
WA 276	Douglas	979.9533	.938 62*	-14.68
GW 36	Sheridan "A"	980.2264	.212 05	-14.35
WA 179	Sheridan "J"	980.2265	.212 14	-14.36

Table A-4  
Comparison of Woollard and Rose Gravimeter Values and IGSN 71  
Values on an Areal Basis in Mexico

		Woollard and Rose	IGSN 71	Diff
BAJA CALIFORNIA SUR				
WA 432	Santa Rosalita	978.1079	.092 45*	-15.45
CAMPECHE				
WA 406	Campeche	978.6519	.636 71*	-15.19
WA 409	Ciudad del Carmen	978.5676	.552 80*	-14.80
CHIAPAS				
WA 435	Tapachula	978.3186	.304 97*	-13.63
CHIHUAHUA				
WA 417	Ciudad Juarez	979.0697	.055 26*	-14.44
WA 429	Parral	978.5372	.523 84*	-13.36
COAHUILA				
WA 430	Saltillo	978.5785	.563 70*	-14.80
WA 437	Torrean	978.6399	.625 50*	-14.40
DISTRITO FEDERAL				
GW 43	Mexico Un. "A"	977.9414	.926 50	-14.90
GW 41	Tacubaya "D"	977.9419	.927 15	-14.75
WA 189	Int'l AP "J"	977.9701	.955 42	-14.68
WA 489	Int'l AP "L"	977.9705	.955 99	-14.51
GW 42	Paso de Cortes "A"	977.5711	.556 36	-14.74
GW 42B	Cortes Mon "C"	977.6536	.638 32	-15.28 Site?
JALISCO				
WA 413	Guadalajara	978.2203	.207 66*	-12.64 Site?
NAYARIT				
WA 436	Tepic	978.4682	.453 22*	-14.98

Table A-4 (cont.)

## Mexico (cont.)

		Woollard and Rose	IGSN 71	Diff
NUEVO LEON				
GW 21	Monterrey "A"	978.8055	.790 69	-14.81
WA 190	Monterrey AP "J"	978.8617	.847 05	-14.65
OAXACA				
WA 435	Tehuantepec	978.4190	.404 04*	-14.96
SAN LUIS POTOSI				
WA 431	San Luis Potosi AP "J"	978.2096	.194 70	-14.90
WA 492	San Luis Potosi "K"	978.2097	.194 78	-14.92
WA 433	Tamuin	978.7589	.744 43*	-14.47
SINOLA				
WA 411	Culican	978.9315	.917 64*	-13.86
WA 420	Los Mochis	978.0199	.005 75*	-14.15
TABASCO				
WA 441	Villahermosa	978.5278	.513 39*	-14.41
TAMAULIPAS				
WA 426	Nuevo Laredo "K"	979.0770	.062 55	-14.45
VERA CRUZ				
WA 440	Vera Cruz	978.5613	.545 89*	-15.41
YUCATAN				
WA 423	Merida	978.6990	.683 51*	-15.49

Table A-5

## Comparison of Woollard and Rose Gravimeter Values and IGSN 71

Values on an Areal basis in Central America and the West Indies

		Woollard and Rose	IGSN 71	Diff
<u>CENTRAL AMERICA</u>				
CANAL ZONE				
WH 1056	Balboa Rodman NB "R"	978.2376	.222 54	-15.06
WH 1057	Cristobal	978.2536	.238 56*	-15.04
GW 92	Ft. Clayton Pend. "A"	978.2417	.226 70	-15.00
US Pend	Ft. Clayton Pend. "O"	978.2391	.224 00	-15.10
WA 4004	Albrook AFB "S"	978.2427	.227 72	-14.98
COSTA RICA				
WA 4049	Golfito	978.2389	.223 98*	-14.92
WA 4043	Liberia	978.1967	.181 79*	-14.91
WA 4046	Los Chiles	978.2443	.229 37*	-14.93
WA 4045	Nicoya	978.2728	.257 87*	-14.93
WA 4007	San Jose "K"	978.9792	.964 36	-14.84
GUATEMALA				
WA 4019	Chahel	978.3717	.356 74*	-14.96
WA 4022	Dos Lagunas	978.4820	.467 02*	-14.98
WA 4011	Guatemala C. "K"	977.9815	.966 80	-14.70
WA 4021	Santo Torbido	978.4020	.387 04*	-14.95
HONDURAS				
WA 4034	Ruinas de Sopan	978.2140	.199 39*	-14.61
WA 4012	Tegucigalpa	978.0869	.072 32*	-14.58
NICARAGUA				
WA 4013	Managua	978.2858	.270 92*	-14.88
	Managua "K"	978.2858	.270 76	-15.04
WA 4036	San Juan del Sur	978.2609	.245 98*	-14.92
WA 4037	Siuna	978.3258	.310 56*	-15.24
PANAMA				
WA 4050	David	978.1616	.146 60*	-15.00
WA 4014	Panama, Tocumen AP	978.2665	.251 44*	-15.06

Table A-5 (cont.)

Central American and West Indies (cont.)

		Woollard and Rose	IGSN 71	Diff
<u>WEST INDIES</u>				
CUBA				
WA 4009	Guantanamo "K"	978.7451	.730 55	-14.55
LEEWARD ISLANDS				
WA 4001	Antigua "B"	978.6544	.638 91	-15.48
PUERTO RICO				
WA 4015	Ramey AFB "K"	978.6602	.645 01	-15.19 ?
WA 4016	San Juan "J"	978.6845	.669 88	-14.62
TRINIDAD				
WA 4003	Port au Spain "J"	978.1622	.146 88	-15.32



Table B

## Comparison of Woollard and Rose Gravimeter Values and IGSN 71

## Values on an Areal basis in South America

		Woollard and Rose	IGSN 71	Diff
ARGENTINA				
WA 6001	Bahia Blanca "K"	980.0683	.052 78	+15.52
	Bahia Blanca	.0683	.052 88*	+15.42
GW 98A	Buenos Aires "A"	979.7048	.690 03	+14.77
Univ	Meter. Obs. "C"	979.7060	.691 16	+14.84
WA 6002	Ezeisa AP "K"	979.7317	.716 75	+14.95
WA 6005	Comodoro Riva. "K"	980.6634	.648 03	+15.37
WA 6004	Cordoba "K"	979.3271	.312 34	+14.76
Univ Base	La Plata "D"	979.7517	.736 85	+14.85
WA 6007	Mar del Plata	980.0181	.002 73 *	+15.37
WA 6008	Oran "K"	978.6381	.623 48	+14.62
WA 6010	Rio Gallegos "K"	981.2066	.191 38	+15.22
	Rio Gallegos	.2066	.191 34*	+15.26
WA 6011	Rio Grande "L"	981.4330	.417 22	+15.78
WA 6012	Salta "K"	978.4985	.483 95	+14.55
WA 6013	San Julian "L"	981.0137	.997 64	+16.06
WA 6014	Santa Cruz	981.0465	.030 24*	+16.26
WA 6015	Santiago del Estero	979.0986	.084 33*	+14.27
WA 6016	Tartagal	978.5938	.578 79*	+15.01
WA 6017	Trelew "K"	980.4539	.438 70	+15.20
WA 6018	Tucuman "K"	978.9060	.982 06	+13.94
Pend	Ushuaia Pent. "A"	981.4807	.465 39	+15.31
BOLIVIA				
WA 6165	Acension	978.3905	.375 55*	+14.95
WA 6167	Camiri	978.3535	.338 73*	+14.77
WA 6173	Cabija	978.1685	.153 60*	+14.90
WA 6162	Cochabamba	977.7945	.779 94*	+14.56
GW 95	La Paz "A"	977.4671	.452 19	+14.91
WA 6134	Braniff AP "K"	977.3528	.338 00	+14.80
WA 6020	Pan Am AP "L"	977.3487	.334 02	+14.68
WA 6175	Magdalena	978.3308	.315 92*	+14.88

Table B (cont.)

## South America (cont.)

		Woollard and Rose	IGSN 71	Diff
WA 6172	Riberalta	978.2378	.222 88*	+14.92
WA 6169	San Ignacio, M	978.3337	.318 76*	+14.94
WA 6166	San Javier	978.3367	.321 82*	+14.88
WA 6174	San Juaquin	978.2975	.282 52*	+14.98
WA 6170	San Ana	978.3388	.323 85*	+14.95
WA 6021	Santa Cruz "K"	978.3639	.349 07	+14.83
WA 6141	Santa Cruz "J"	978.3643	.349 44	+14.86
WA 6163	Sucre	977.7915	.776 70*	+14.80
WA 6168	Trinidad	978.3374	.322 70*	+14.70
BRAZIL				
WA 6022	Acu	978.0839	.069 02*	+14.88
WA 6023	Alegrete	979.2926	.277 41*	+15.19
WA 6024	Anapolis	978.1489	.134 01*	+14.89
WA 6026	Aracati	978.0979	.083 02*	+14.88
WA 6027	Aracatuba	978.5808	.565 80*	+15.00
WA 6028	Aragarcas	978.3196	.304 66*	+14.94
WA 6030	Araquari	978.2764	.261 47*	+14.93
WA 6031	Bage	979.4128	.397 58*	+15.22
GW 108	Belem "A"	978.0374	.022 24	+15.16
WA 6032	Belem AP "K"	978.0342	.018 97	+15.23
WH 1012	Tide Gage "O"	978.0397	.024 59	+15.11
WH 1055	Pier "N"	978.0399	.024 63	+15.27
WA 6033	Belo Horizonte	978.4003	.385 50*	+14.80
WA 6035	Brasilia "K"	978.1013	.086 07	+15.23
WA 6142	Brasilia "J"	978.1001	.084 92	+15.18
WA 6036	Caceres	978.3968	.381 84*	+14.96
WA 6037	Campo Grande	978.5065	.491 52*	+14.98
WA 6039	Campos "J"	978.7326	.717 49	+15.11
WA 6041	Caravelas "J"	978.5270	.511 46	+15.54
WA 6042	Carolina "J"	978.0461	.031 11	+14.99
WA 6029	Conceicao A	978.0449	.030 03*	+14.87
WA 6043	Cruz Alta	979.1207	.105 55*	+15.15
WA 6044	Cruzeiro do Sul	978.1081	.093 21*	+14.89
WA 6045	Cuiaba	978.3590	.344 05*	+14.95

Table B (cont.)

South America (cont.)

		Woollard and Rose	IGSN 71	Diff	
WA 6046	Curitiba	978.7895	.774 45*	+15.05	
WA 6047	Esplanada	978.2614	.246 48*	+14.92	
WA 6048	Fazenda Si Juan	978.4820	.467 02*	+14.98	
WA 6051	Florinapolis "J"	979.1338	.118 93	+14.87	
WA 6053	Fortaleza "J"	978.0822	.067 81	+14.39	site?
WA 6055	Goiania "J"	978.2403	.225 40	+14.90	
WA 6056	Grajau	977.9848	.969 95*	+14.85	
WA 6057	Guajara Mirim	978.2172	.202 28*	+14.92	
WA 6058	Iquassu Falls	978.9191	.904 01*	+14.99	
WA 6059	Ilheus	978.4617	.446 87*	+14.83	
WA 6060	Imperatriz	978.0195	.004 39*	+15.11	
WA 6154	Itacoatiara	978.0165	.001 64*	+14.86	
WA 6061	Joao Pessoa "J"	978.1443	.129 03	+15.27	
		978.1443	.129 18*	+15.12	
WA 6062	Livramento	979.3357	.320 50*	+15.20	
WA 6155	Londrina	978.6518	.636 77*	+15.03	
WA 6063	Maceio	978.1429	.128 07*	+14.83	
WA 6064	Manaus "J"	978.0213	.006 16	+15.14	
		978.0213	.006 27*	+15.03	
WA 6065	Maraba	978.0364	.021 53*	+14.87	
WA 6066	Mossoro	978.0926	.077 45*	+15.15	
WA 6067	Natal	978.1151	.099 85*	+15.25	
WA 6068	Paracatu	978.2596	.244 67*	+14.93	
WA 6069	Parana	978.1699	.155 00*	+14.90	
WA 6070	Parnaiba	978.0372	.020 62*	+16.58	site?
WA 6071	Paulo Afonso	978.0951	.081 79*	+14.31	
WA 6072	Peixe	978.1981	.183 03*	+15.07	
WA 6074	Porto Alegre "J"	979.3158	.300 78	+15.02	
WA 6159	Porto Guaira	978.8091	.794 03*	+15.07	
WA 6075	Porto Nacional "J"	978.1605	.145 44	+15.06	
WA 6076	Porto Seguro	978.4661	.451 12*	+14.98	
WA 6077	Porto Velho	978.1444	.129 51*	+14.89	
WA 6079	Recife "J"	978.1665	.151 25	+15.25	

Table B (cont.)

## South America (cont.)

		Woollard and Rose	IGSN 71	Diff
WH 1059	Harbor "M"	978.1777	.162 52	+15.18
WA 6080	Rio Branco	978.1582	.143 30*	+14.90
GV 109	Rio de Janeiro "A"	978.8047	.789 90	+14.80
WA 6082	Galeao AP "J"	978.7978	.783 05	+14.75
WA 6081	S. Dumont "L"	978.8084	.793 55	+14.85
WH 1060	Pier Praca N. "O"	978.8076	.792 78	+14.82
WA 6083	Salvador "J"	978.3443	.329 43	+14.87
WA 6084	Santa Maria	979.2771	.261 91*	+15.19
WA 6153	Santarem	978.0468	.031 93*	+14.87
WA 6086	Sao Borja	979.2040	.188 84*	+15.16
WA 6151	Sao Luis	977.9901	.975 52*	+14.58
WA 6088	Sao Mateus	978.5719	.556 90*	+15.00
WA 6090	Sao Paulo "M"	978.6508	.635 56	+15.24 site?
		978.6508	.636 23*	+14.57
WA 6091	Sena Madureira	978.1569	.142 00*	+14.90
WA 6092	Tarauaca	978.1403	.125 41*	+14.89
WA 6149	Tefe "J"	978.0472	.031 88	+15.32
WA 6093	Teresina	978.0320	.01710*	+14.90
WA 6094	Tocantinapolis	978.0440	.029 13*	+14.87
WA 6095	Tocantinia	978.1092	.094 31*	+14.89
WA 6096	Tres Lagos	978.5717	.556 70*	+15.00
WA 6097	Uberaba	978.3609	.345 39*	+15.51
WA 6158	Uruguiana	979.3075	.292 31*	+15.19
WA 6100	Villa Bella	978.3408	.325 85*	+14.95
WA 6101	Vitoria "J"	978.6537	.638 25	+15.45
WA 6102	Xabantina	978.2837	.268 77*	+14.93
WA 6103	Xapuri	978.1898	.174 89*	+14.91
CHILE				
GW 99	Antofogasta "A"	978.9045	.889 52	+14.98
WA 6105	Cerro Moreno AP "K"	978.8853	.870 30	+15.00
WA 6135	Old AP "L"	978.8830	.868 04	+14.96
WA 6106	Arica, Old AP "N"	978.5111	.495 82	+15.28
WA 6144	Intl AP "L"	978.4939	.478 54	+15.36

Table B (cont.)

## South America (cont.)

		Woollard and Rose	IGSN 71	Diff
WA 6160	Concepcion	979.9698	.954 44*	+15.36
WA 6147	Puerto Montt "J"	980.2976	.282 22	+15.38
WA 6148	Chameza AP "K"	980.3041	.288 74	+15.36
GW 97	Punta Arenas "A"	981.3159	.300 49	+15.41
WA 6108	Chabunco AP "K"	981.3122	.296 70	+15.50
WA 6136	Chabunco AP "L"	981.3130	.297 61	+15.39
WH 1019	Port Adm. "N"	981.3363	.320 81	+15.49
GW 96	Santiago "A"	979.4294	.414 11	+15.29
WA 6110	Los Cerillos AP "K"	979.4500	.434 68	+15.32
WA 6109	Los Cerillos "J"	979.4493	.434 24	+15.06
WH 1020	Valparaiso Pier "K"	979.6362	.620 87	+15.33
WH 1058	Valparaiso L. H. "L"	979.6342	.618 90	+15.30
COLOMBIA				
WA 6111	Barranquilla "J"	978.2265	.211 56	+14.94
WH 1066	Port "K"	978.2393	.224 27	+15.03
GW 106	Bogota "A"	977.4049	.390 11	+14.79
WA 6112	Techo AP "J"	977.4017	.386 91	+14.76
WA 6145	Eldorado AP "K"	977.3954	.380 59	+14.81
WA 6113	Cali "J"	977.8197	.804 89	+14.81
WA 6114	Cartagena	978.1965	.181 59*	+14.91
WA 6181	Chafarray	977.9887	.973 84*	+14.81
WA 6116	Ipiates	977.2532	.238 53*	+14.67
Pend	Medellin	977.7547	.740 66*	+14.24 site?
WA 6118	Pereira	977.7740	.759 20*	+14.80
WA 6119	Popayan "K"	977.5998	.584 49	+15.31 site?
WA 6179	San Juan	977.8964	.881 57*	+14.83
WA 6178	Villavicencio	977.8676	.852 77*	+14.83
ECUADOR				
WA 6120	Guayaquil "M"	978.1391	.123 71	+15.39
WA 6146	Guayaquil AP "K"	978.1447	.129 34	+15.46
WA 1067	Pier "N"	978.0918	.076 30	+15.50
WA 6177	Manta	978.1017	.086 81*	+14.89
GW 106	Quito "A"	977.2777	.263 19	+14.51

Table B (cont.)

## South America (cont.)

		Woollard and Rose	IGSN 71	Diff
WA 6121	Panagra AP "J"	977.2860	.271 44	+14.56
WA 6139	Mariscal Sucre AP	977.2849	.270 38 *	+14.52
FRENCH GUIANA				
WA 6122	Cayenne	978.0387	.023 83 *	+14.87
GUYANA (British Guiana)				
WA 6104	Georgetown "K"	978.0909	.075 55	+15.35
WA 6143	New Term. "J"	978.0911	.075 70	+15.40
WH 1062	Harbor "L"	978.1179	.102 48	+15.42
PARAGUAY				
WA 6123	Assuncion "J"	978.9583	.943 12	+15.18
PERU				
WA 6124	Arequipa "K"	977.7165	.701 73	+14.77
WA 6125	Iquitos "J"	978.0876	.072 11	+15.49
GW 93	Lima "A"	978.2830	.267 94	+15.06
WA 6126	Limatambo AP "J"	978.2791	.264 08	+15.02
WA 6140	Callao Intl "K"	978.3072	.292 18	+15.02
WH 1068	Callao Pier "M"	978.3127	.297 79	+14.91
WA 6176	Pucallpa	978.0550	.040 13 *	+14.87
WA 6127	Talara	978.1336	.118 64 *	+14.96
SURINAM				
WA 6128	Paramaribo "J"	978.0471	.033 50	+13.60 site?
URAGUAY				
WA 6129	Montevideo "K"	979.7465	.731 56	+14.94
VENEZUELA				
WA 6130	Barcelona	978.1505	.135 63 *	+14.87
WA 6193	Caicara	978.1247	.111 08 *	+13.62 site?
WA 6191	Calabazo	978.1679	.153 69 *	+14.21 site?
GE 107	Caracas "A"	978.0399	.024 72	+15.18
WA 6131	Maiquetia AP "K"	978.2460	.231 06	+14.94
WH 1071	La Guayra Hrb. "L"	978.2522	.237 24	+14.96
WA 6185	Casigua	978.1170	.102 12 *	+14.88
WA 6190	Coro	978.2374	.222 48 *	+14.92

Table B (cont.)

South America (cont.)		Woollard and Rose	IGSN 71	Diff
WA 6133	Maturia "J"	978.0112	.966 31	+14.89
WA 6187	Merida	977.7506	.735 92*	+14.68
WA 6194	Puerto Paez	978.0818	.066 92*	+14.88
WA 6184	San Antonio	977.9430	.927 57*	+15.43 site?
WA 6192	San Fernando Apure	978.1412	.126 30*	+14.90

Table C

## Comparison of Woollard and Rose Gravimeter Values and IGSN 71

## Values on an Areal Basis in Europe

		Woollard and Rose	IGSN 71	Diff. Mgal
CYPRUS				
Pend.	Nicosia	979.8492	.83449*	+14.71
DENMARK				
GW 64	Copenhagen "B"	981.5577	.54319	+14.51
WA 5004	Kastrup AP "J"	981.5573	.54275	+14.55
WA 5059	Kastrup AP "L"	981.5568	.54226	+14.54
EIRE (Ireland)				
Pend. Base	Dublin (Dunsink Obs.)	981.3891	.37478*	+14.32
FINLAND				
Pend. Base	Helsinki "A"	981.9152	.90059	+14.61
WA 5019	Seutula AP "S"	981.9248	.91009	+14.71
FRANCE				
WA 5022	Bordeaux	980.5816	.56694*	+14.66
WA 5023	Marseille "J"	980.4880	.47355	+14.45
GW 114	Paris "A"	980.9409	.92597	+14.93
Gm Base	Obs. "B"	980.9434	.92865	+14.75
Nat'l Base	Obs. "E"	980.9432	.92829	+14.91
WA 5058	Orly AP "N"	980.9160	.90101	+14.99
WA 5024	Le Bourget AP "J"	980.9502	.93534	+14.86
ITALY				
WA 5032	Naples "R"	980.2568	.24204	+14.76
GW 61	Rome "A"	980.3639	.34923	+14.67



Table C (cont.)

Europe (cont.)		Woollard and Rose	IGSN 71	Diff. Mgal
Nat'l Base Rome "B"		980.3619	.34722	+14.68
	Roca de Papa Obs. "C"	980.1929	.17843	+14.47
WA 5033	Ciampino Est "J"	980.3489	.33427	+14.63
WA 5034	Ciampino Ovest "M"	980.3478	.33319	+14.61
WA 5060	Fiumicino Int'l "N"	980.3765	.36176	+14.74
NETHERLANDS				
WA 5036	Amsterdam "J"	981.2882	.27340	+14.80
Pend.	DeBilt Obs.	981.2693	.25456*	+14.74
NORWAY				
CW 117	Bodo "A"	982.3873	.37265	+14.65
WA 5037	Airport "J"	982.3876	.37297	+14.63
CW 118	Hammerfest "A"	982.6324	.61762	+14.78
WH 1045	Indrefjord "J"	982.6301	.61548	+14.62
CW 68	Oslo "A"	981.9272	.91261	+14.59
WA 5038	Fornebu AP "J"	981.9367	.91620	+14.50
WA 5039	Tromsø "K"	982.5710	.55711	+13.89 site?
Pend.	Trondheim "A"	982.1614	.14674	+14.66
WA 5040	Vaernes AP "K"	982.1523	.13779	+14.51
PORTUGAL				
CW 110	Lisbon "A"	980.0903	.07573	+14.57
WA 5041	Airport "K"	980.0796	.06512	+14.48
SPAIN				
Pend.	Madrid Astro. Obs. "A"	979.9812	.96652	+14.68
Gm Base	IGC "C"	979.9703	.95561	+14.69

Table C (cont.)

Europe (cont.)		Woollard and Rose	IGSN 71	Diff. Mgal
WA 5049	Barajas AP "J"	979.9988	.98414	+14.64
WA 5051	Torrejon AFB "M"	980.0072	.99251	+14.69
SWEDEN				
Pend.	Stockholm "A"	981.8465	.83143	+15.07
WA 5053	Bromma AP "J"	981.8455	.83066	+14.84
SWITZERLAND				
WA 5054	Geneva "J"	980.5889	.57444	+14.46
Pend.	Zurich Geod. Inst. "A"	980.6670	.65213	+14.87
WA 5055	Kloten AP "J"	980.6871	.67218	+14.92
UNITED KINGDOM				
Pend.Sta.	Aberdeen Univ.	981.6998	.68482*	+14.98
Pend.Sta.	Cambridge Univ.	981.2688	.25394*	+14.86
Pend.Sta.	Edinburgh Obs. "A"	981.5839	.56897	+14.93
WA 5047	Prestwick AP "J"	981.5784	.56351	+14.89
WA 5046	Prestwick MATS "K"	981.5758	.56113	+14.67
WA 5044	Glasgow "N"	981.6018	.58692	+14.88
GW 67	Teddington "A"	981.1966	.18178	+14.82
WA 5012	London AP (1) "J"	981.2003	.18558	+14.72
WA 5013	Old Term. "M"	981.2017	.18704	+14.66
Pend.	York	981.4183	.40380*	+14.50
WEST GERMANY				
GW 63	Bad Harzburg "A"	981.1803	.16550	+14.80
GW 63A	Braunschweig "C"	981.2668	.25184	+14.96

Table C (cont.)

Europe (cont.)		Woollard and Rose	IGSN 71	Diff. Mgal
GW 62	Frankfurt "A"	981.0610	.04632	+14.68
WA 5028	Airport "J"	981.0571	.04243	+14.67
WA 5064	Hamburg "J"	981.3943	.37969	+14.61
WA 5063	Hannover "K"	981.2875	.27261	+14.88

Table D

Comparison of Woollard and Rose Gravimeter Values and IGSN 71  
Values on an Areal Basis in Africa

		Woollard and Rose	IGSN 71	Diff. Mgal
ALGERIA				
WA 1001	Algiers "J"	979.9057	.89139	+14.31
EGYPT				
WH 1023	Alexandria Port	979.4331	.41921*	+13.89 site?
GW 69	Cairo "B"	979.2915	.27676	+14.74
WA 1002	Farouk AP "L"	979.3160	.30125	+14.75
WA 1004	Port Said "K"	979.4528	.43764	+15.16
WH 1026	Suez	979.3069	.29221*	+14.69
ETHIOPIA				
WA 1006	Addis Ababa "L"	977.4783	.46396	+14.34
GW 76	Asmara "A"	977.8194	.80545	+13.95
WA 1005	Mun. AP "J"	977.8224	.80826	+14.14
WA 1007	Debra Markus	977.5107	.49416*	+15.54 site?
WA 1008	Gondar	977.7060	.65126*	+14.74
WA 1009	Tessenai "J"	978.1902	.17580	+14.40
GAMBIA				
WA 1011	Bathurst "J"	978.3535	.33875	+14.55
GHANA				
GW 112	Accra "A"	978.1059	.09141	+14.49
WA 1012	Airport "J"	978.1153	.10052	+14.78
GUINEA				
WA 1036	Conakry "J"	978.2264	.21094	+15.46

Table D (cont.)

Africa (cont.)		Woodward and Rose	IGSN 71	Diff. Mgal
KENYA				
GW 71	Nairobi "A"	977.5403	.52607	+14.23
Camb.	Bullard (L) "C"	977.5279	.51375	+14.15
WA 1014	Eastleigh "J"	977.5430	.52877	+14.23
WA 1015	West Civil "K"	977.5357	.52151	+14.19
LIBYA				
WA 1019	Benghazi	979.5264	.51170*	+14.70
GW 60	Tripoli "A"	979.5876	.57272	+14.88
WA 1021	Idris AP "L"	979.5379	.52300	+14.90
WA 1020	Wheeler AFB "K"	979.5876	.57274	+14.86
MALAGASY				
WA 9006	Tananarive "J"	978.2166	.20242	+14.18
MOROCCO				
WA 1023	Casablanca "J"	979.6428	.62796	+14.84
WA 1026	Tangier "J"	979.7492	.73401	+15.19 site?
MOZAMBIQUE				
WA 1027	Beira	978.6252	.61049*	+14.71
WA 1028	Lourenco Marques	979.0527	.03801*	+14.69
NIGERIA				
WA 1029	Kano "J"	978.1357	.12092	+14.78
RHODESIA				
WA 1042	Bulawayo "J"	978.2921	.27754	+14.56
WA 1043	Salisbury "J"	978.1484	.13414	+14.26
Pend.	Salisbury "A"	978.1481	.13365	+14.45
Pend.	Victoria Falls	978.2314	.21689*	+14.51

Table D (cont.)

Africa (cont.)		Woollard and Rose	IGSN 71	Diff. Mgal
SENEGAL				
CW 111	Dakar Mbour "B"	978.3852	.37039	+14.81
WA 1010	Yof AP "J"	978.4772	.46242	+14.78
SOMALI				
WA 1041	Mogadiscio	978.0779	.06318*	+14.72
SOUTH AFRICA				
WA 1055	Bloemfontein	978.8537	.83900*	+14.70
CW 74	Capetown "A"	979.6473	.63271	+14.59
Pend.	Royal Obs. "B"	979.6535	.63893	+14.57
WA 1057	Malam AP "J"	979.6462	.63145	+14.75
WA 1056	Wingfield AP "L"	979.6494	.63484	+14.56
CW 73	Johannesburg "A"	978.5495	.53546	+14.04
WA 1062	L. Smuts AP "K"	978.5503	.53610	+14.20
WA 1063	Kimberley "J"	978.8881	.87371	+14.39
WA 1067	Port Elizabeth	978.6514	.63571*	+15.69 site?
Pend.	Pretoria "A"	978.6296	.61530	+14.30
WA 1071	Uppington	978.9831	.97040	+14.70
SOUTHWEST AFRICA				
WA 1065	Ohopoho	978.2136	.19887*	+14.73
WA 1070	Tsumeb	978.2209	.20619*	+14.71
WA 1022	Windhoek	978.3210	.30629*	+14.71
SUDAN				
CW 70	Khartoum "B"	978.3034	.28867	+14.73
CW 70A	Univ. Pend. "A"	978.3033	.28864	+14.66
WA 1045	Airport "L"	978.3034	.28865	+14.75

Table D (cont.)

Africa (cont.)		Woollard and Rose	IGSN 71	Diff. Mgal
WA 1047	Port Sudan "K"	978.6404	.62599	+14.41
TANZANIA				
WA 1048	Dar es Salaam "K"	978.1165	.10011	+16.39 site?
WA 1049	Dodoma	977.7535	.73930*	+14.20
WA 1050	Mbeya "K"	977.6840	.66989	+14.11
WA 1051	Moshi "K"	977.7720	.75788	+14.12
WA 1052	Tabora "J"	977.6844	.66995	+14.45
TUNISIA				
WH 1054	Sfax Harbor	979.7267	.71202*	+14.68
WA 1053	Tunis	979.9061	.89992*	+16.18 site?
UGANDA				
WA 1054	Entebbe "J"	977.7241	.70984	+14.26
ZAIRE (CONGO)				
CW 113	Leopoldville "A"	977.9146	.89982	+14.78
WA 1037	Int'l. AP "J"	977.9518	.93713	+14.67
WA 1038	Ndjili AP "M"	977.9429	.92820	+14.70
ZAMBIA (N. RHODESIA)				
WA 1030	Abercorn "J"	977.6707	.65662	+14.08
WA 1031	Kasama "J"	977.7877	.77354	+14.16
WA 1033	Lasapa "J"	978.0534	.03932	+14.08
WA 1034	Ndola "K"	977.9126	.89830	+14.30

Table E

## Comparison of Woollard and Rose Gravimeter Values and IGSN 71

## Values on an Areal Basis in Southwest Asia and South Asia

		Woollard and Rose	IGSN 71	Diff. Mgal
BAHREIN				
WA 2002	Muharraq	979.0147	.99963 *	+15.07
CEYLON				
Colombo				
Pend.	Met. Obs. "B"	978.1328	.11724	+15.56
Pend.	Fr. Consul "C"	978.1403	.12454	+15.76
WA 2004	Ratmalana AP "J"	978.1323	.11690	+15.40
INDIA				
WA 2010	Amritsar "J"	979.3484	.33506	+13.34 site?
Pend.	Bangladore "A"	978.0294	.01389	+15.51
WA 2011	Bangladore "J"	978.0387	.02314	+15.56
WA 2013	Calcutta "J"	978.8077	.79281	+14.89
Nat'l Base	Dehra Dun "A"	979.0636	.04909	+14.51
WA 2016	Hyderabad "J"	978.3347	.31958	+15.12
WA 2017	Jammu	979.3041	.29004*	+14.06
Pend.	Madras "A"	978.2818	.26658	+15.25
WA 2018	Madras AP "J"	978.2804	.26516	+15.24
GW 59	New Delhi "A"	979.1363	.12155	+14.75
WA 2019	Palam AP "J"	979.1341	.11938	+14.72
WA 2020	Willingdon AP "K"	979.1379	.12316	+14.74
WA 2021	Srinagar	979.0443	.03013	+14.17



Table E (cont.)

Southwest Asia and South Asia (cont.)

		Woollard and Rose	IGSN 71	Diff. Mgal
IRAN				
WA 2023	Tehran "J"	978.4491	.43068	+18.42 site?
IRAQ				
WA 2024	Ain Zalah	979.7840	.76933*	+14.67
WA 2025	Baghdad	979.5469	.53222*	+14.68
WA 2026	Basrah	979.3240	.30931*	+14.69
WA 2027	Kirkuk	979.5991	.64272*	+14.68
KUWAIT				
WA 2049	Al Kuwait	979.2688	.25411*	+14.69
LEBANON				
Pend.	Beirut "A"	979.6909	.67625	+14.65
WA 2050	Khalde AP <sub>1</sub> "J"	979.6934	.67864	+14.76
WA 2051	Khalde AP <sub>2</sub> "K"	979.6922	.67744	+14.76
PAKISTAN				
WA 2059	Karachi	978.9620	.94730*	+14.70
QATAR				
WA 2064	Dukhan	978.9528	.93810*	+14.70
SAUDI ARABIA				
WA 2067	Abu Hadriyah	979.1084	.09370*	+14.70
WA 2068	Dhahran	978.9990	.98430*	+14.70
WA 2069	Jidda	978.7556	.75222*	+13.38 site?
WA 2070	Ras Al Mishab	979.1696	.15491*	+14.69

Table E (cont.)

## Southwest Asia and South Asia (cont.)

		Woollard and Rose	IGSN 71	Diff. Mgal
TRUCIAL STATES				
WA 2075	Sharjah	978.9026	.88790*	+14.70
TURKEY				
WA 2076	Ankara "M"	979.9500	.93548	+14.52
WA 2077	Izmir	980.0231	.00842*	+14.68
YEMEN				
WA 2001	Aden "J"	978.3179	.30432	+13.58 site?

Table 1  
 Comparison of Woollard and Rose Gravimeter Values and IGSN 71  
 Values on an Areal Basis in Southeast Asia and East Asia

		Woollard and Rose	IGSN 71	Diff. Mgal
CAMBODIA				
WA 2003	Phnom Penh "J"	978.2390	.22308	+15.82
FEDERATION OF MALAYSIA				
	<u>Sabah (North Borneo)</u>			
WA 2054	Jesselton	978.1279	.11318*	+14.72
WA 2055	Labuan Is.	978.0960	.08128*	+14.72
WA 2056	Sandakan	978.0914	.07668*	+14.72
	<u>Sarawak</u>			
WA 2065	Kuching	978.0763	.06158*	+14.72
WA 2066	Sibu	978.0790	.06428*	+14.72
HONG KONG				
GW 101	Am. Consulate "A"	978.7677	.75231	+15.39
WA 2008	Kai-Tak AP "J"	978.7730	.75766	+15.34
Pend.	Kowloon Roy. Obs. "B"	978.7712	.75585	+15.35
INDONESIA				
WA 3045	Djakarta	978.1644	.14968*	+14.72
NEW CALEDONIA				
WA 7016	Tontouta	978.8590	.84430*	+14.70
NEW GUINEA AREA and BISMARCK ARCHIPELAGO				
	<u>New Britain Is.</u>			
WA 3011	Rabaul	978.1643	.15001*	+14.29

Table F (cont.)

Southeast Asia and East Asia (cont.)

		Woollard and Rose	I' SN 71	Diff. Mgal
<u>New Ireland Is.</u>				
WA 3081	Kavieng	978.1668	.15208*	+14.72
<u>Papua</u>				
WA 3069	Port Moresby "J"	978.2129	.19833	+14.57
<u>Terr. of New Guinea</u>				
WA 3084	Aitape	978.1707	.15598*	+14.72
WA 3077	Goroka	977.6994	.68467*	+14.73
WA 3076	Lae	978.0140	.99614*	+17.86 site?
WA 3078	Madang	977.9701	.95504*	+15.06
WA 3086	Vanima	978.1997	.18498*	+14.72
WA 3079	Wewak	978.0965	.08158*	+14.92
<u>West Irian</u>				
WA 3098	Biak Is.	978.1237	.10898*	+14.72
WA 3097	Hollandia	978.1721	.15737*	+14.73
WA 3099	Manokwari	978.0869	.07218*	+14.72
WA 3068	Noemfoor Is.	978.1409	.12618*	+14.72
WA 3096	Sarmi	978.1461	.13137*	+14.73
WA 3101	Sorong	978.1401	.12537*	+14.73
PHILIPPINES				
GW 58	Clark AFB "A"	978.3969	.38230	+14.60
WA 2061	Clark MATS "J"	978.3965	.38183	+14.67
WA 2062	Manila Intl. AP "K"	978.3767	.36192	+14.78
WH 1048	Manila Pier "N"	978.3562	.34142	+14.78

Table F (cont.)

Southeast Asia and East Asia (cont.)

		Woollard and Rose	IGSN 71	Diff. Mgal
SINGAPORE				
GW 102	Univ. Malaya "A"	978.0815	.06668	+14.82
Pend.	Raffles Mus. "B"	978.0809	.06604	+14.86
WA 2071	Changi RAF "E"	978.0801	.06521	+14.89
WA 2072	Kallang AP "J"	978.0817	.06681	+14.89
WA 2073	Paya Lebar "L"	978.0804	.06561	+14.79
SOLOMON ISLANDS				
WA 3075	Honiara	978.2742	.25984*	+14.36
WA 3073	Munda	978.2541	.23938*	+14.72
TAIWAN				
WA 2007	Taipei "J"	978.9725	.95946	+13.04 site?
THAILAND				
WA 2074	Bangkok "J"	978.3297	.31485	+14.85
VIETNAM				
WA 2078	Hanoi	978.6888	.67409*	+14.71
WA 2079	Hue	978.4367	.42198*	+14.72
WA 2080	Nha-Trang	978.2624	.24769*	+14.71
WA 2081	Saigon "J"	978.2300	.21509	+14.91
EAST ASIA				
JAPAN				
WA 2032	Itani "J"	979.7171	.70375	+13.35 site ?
WA 2033	Iwakuni	979.6522	.63752*	+14.68
Pend.	Kyoto "A"	979.7216	.70727	+14.33

Table F (cont.)

Southeast Asia and East Asia (cont.)

		Woollard and Rose	IGSN 71	Diff. Mgal
WA 2034	Misawa	980.3200	.30534*	+14.66
WA 2035	Tachikawa "S"	979.7880	.77398	+14.02
GW 103	Tokyo "A"	979.8016	.78722	+14.38
WA 2037	Haneda AP "L"	979.7736	.75916	+14.44
GW 103	Sapporo "B"	980.4406	.42735	+13.25
WA 2030	Chitose AP "J"	980.4405	.42734	+13.16
SOUTH KOREA				
WA 2045	Pusan	979.7780	.77405*	+13.95
WA 2047	Seoul "K"	979.9722	.95847	+13.73
	Seoul "J"	.9722	.95863	+13.57
OKINAWA				
GW 100	Kadena "A"	979.1265	.11222	+14.28
WA 2057	Kadena MATS "J"	979.1343	.11992	+14.38

Table G

## Comparison of Woollard and Rose Gravimeter Values and IGSN 71

## Values on an Areal Basis in Australia and New Zealand

		Woollard and Rose	IGSN 71	Diff Mgal
AUSTRALIA				
Pend.	Adelaide	979.7243	.709 20*	+15.10
WA 3003	Alice Springs "J"	978.6541	.639 39	+14.71
GW 85	Brisbane "B"	979.1695	.155 16	+14.34
GW 85 A	Univ. Seismic Sta. "A"	979.1701	.155 93	+14.17
WA 3004	Eagle Farm AP "J"	979.1599	.145 57	+14.33
WA 3067	Archer AP "K"	979.1683	.154 11	+14.19
GW 87	Cairns "A"	978.5006	.486 24	+14.36
WA 3009	Carnovan	978.9447	.928 83*	+15.87 site?
WA 3010	Ceduna	979.4534	.438 07*	+15.33
WA 3059	Daly Waters	978.3892	.374 87	+14.33 *
GW 88	Darwin "A"	978.3140	.299 55	+14.45
WA 3058	RAF Club "B"	978.3164	.301 92	+14.48
WA 3014	Airport "J"	978.3154	.300 93	+14.47
WA 3015	Derby	978.5207	.505 69*	+15.01
WA 3016	Forrest	979.3068	.292 26*	+14.54
WA 3022	Kalgoorlie	979.2911	.276 95*	+14.15
WA 3025	Leigh Creek	979.3204	.306 76*	+13.64 site?
WA 3026	Mackay	979.7339	.720 77*	+13.13 site?
WA 3027	Maryborough "A"	979.0219	.007 32	+14.58
GW 83	Melbourne "A"	979.9797	.965 18	+14.52
WA 3028	Essendon AP "J"	979.9628	.948 21	+14.59
	Kallista For. R. "S"	979.9100	.895 38	+14.62
WA 3031	Mount Isa "J"	978.6190	.604 41	+14.59
WA 3033	Oodnadatta	979.1006	.086 44*	+14.16
WA 3034	Onslow	978.7749	.758 81*	+16.09 site?
Pend	Perth Univ "A"	979.3958	.380 86	+14.94
WA 3035	Airport "K"	979.4011	.386 32	+14.78
WA 3036	Port Hedland	978.6466	.631 50*	+15.10
Pend	Rockhampton "A"	978.8707	.856 06	+14.64
WA 3038	Airport "J"	978.8738	.859 35	+14.45

Table G (cont.)

Australia - New Zealand (cont.)

			IGSN 71	Diff Mgal
GW 84	Sydney "A"	979.6863	.671 86	+14.44
WA 3042	Kingsford S. "J"	979.6993	.684 80	+14.50
WA 3041	Rose Bay "L"	979.6965	.681 98	+14.52
WA 3042	Tennant Creek	978.5290	.513 69*	+15.31
GW 86	Townsville "B"	978.6247	.610 43	+14.27
WA 3043	Airport "C"	978.6240	.609 66	+14.34
WA 3044	Wyndham	978.4171	.402 18*	+14.92
NEW ZEALAND				
Pend	Auckland Mus. "B"	979.9487	.934 11	+14.59
WA 3047	Whenuapai AP "C"	979.9408	.926 04	+14.76
GW 79	Christchurch "A"	980.5089	.494 29	+14.61
WA 3103	Intl. AP "L"	980.4962	.481 59	+14.61
WA 3049	Harewood AP "K"	980.4962	.481 47	+14.73
GW 89	Dunedin "A"	980.7424	.727 53	+14.87
WA 3051	Taieri AP "C"	980.7366	.721 75	+14.85
WA 3053	Hastings	980.0881	.073 87*	+14.23
GW 81	Wellington "C"	980.2934	.279 09	+14.31
Pend Base	Wellington DSIR "A"	980.2656	.251 00	+14 60
WA 3058	Rongotai AP "K"	980.3064	.292 01	+14.39



Table H

Comparison of Woollard and Rose Gravimeter Values and IGSN 71  
Values on an Areal Basis in Oceanic Islands

		Woollard and Rose	IGSN 71	Diff. Mgal
<u>ATLANTIC AREA</u>				
ASCENSION				
WA 7001	Ascension Is. "J"	978.2943	.27939	+14.91
AZORES				
WA 7002	Lages, Terceira "J"	980.1762	.16142	+14.67
WA 7003	Santa Maria "L"	980.1167	.10235	+14.35
BERMUDA				
WA	Kindley "J"	979.8093	.79402	+15.28
WH 1007	Biol. Sta. "P"	979.8232	.80807	+15.13
GREENLAND				
WA 319	Sondre Stromfjord "J"	982.3843	.37011	+14.19
WA 320	Thule "J"	982.9280	.91375	+14.25
ICELAND				
WA 7006	Keflavik "K"	982.2744	.25943	+14.97
Natl Base	Reykjavik "A"	982.2800	.26496	+15.04
WA 7007	Reykjavik AP "L"	982.2784	.26333	+15.07
WH 1035	Reykjavik Pier "J"	982.2813	.26634	+14.96
<u>PACIFIC AREA</u>				
FIJI				
WA 7010	Nandi "J"	978.5471	.53281	+14.29
WA 7009	Suva	978.6242	.60939*	+14.81
GUAM				
WA 7011	Agana NAS "J"	978.5240	.50903	+14.97

Table H (cont.)

Oceanic Islands (cont.)

		Woollard and Rose	IGSN 71	Diff. mGal
HAWAIIAN ISLANDS				
Honolulu				
GW 55	Bishop Mus. "B"	978.9530	.93835	+14.65
Pend.	Univ. "A"	978.9593	.94490	+14.40
WA 443	Hickam AFB "J"	978.9337	.91914	+14.56
WA 444	Old Int'l AP "S"	978.9325	.91810	+14.40
WA 7015	Midway Is. "J"	979.4993	.48460	+14.70
WH 1041	Pier "P"	979.5077	.49222	+15.48 site?
LINE ISLANDS				
WA 7013	Johnston Is.	978.7198	.70514*	+14.66
NEW CALEDONIA				
WA 7016	Tontouta	978.8590	.84430*	+14.70
PHOENIX ISLANDS				
WA 7017	Canton Is. "J"	978.2932	.27880	+14.40
SAMOA				
WA 7019	Pago Pago "J"	978.6407	.62616	+14.54
SOCIETY ISLANDS				
WA 7020	Bora Bora	978.6703	.65559*	+14.71
WA 7022	Papeete "J"	978.7086	.69353	+15.07
TONGA				
WA 7023	Fua-Amotu AP	978.8722	.85749*	+14.71
WAKE				
WA 7024	Wake Is. "J"	978.8814	.86656	+14.84

Table H (cont.)

<u>Oceanic Islands (cont.)</u>		Woodward and Rose	ICSN 71	Diff. Mgal
WALLIS ISLAND				
WA	Wallis Is.	978.5215	.50679*	+14.71
<u>INDIAN OCEAN AREA</u>				
WA 9004	Cocos (Keeling Is.) "J"	978.4687	.45454	+14.16 site?
WA 9005	Heard Island	981.4778	.46318*	+14.62
WA 9017	Kerguelen Is.	981.0734	.05876*	+14.64
WA 9007	Mauritius Is.	978.8666	.85221*	+14.39

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#### ABSTRACT

The history of improvements in the global standardization of gravity values since the advent of high range gravimeters in 1948 is reviewed. In particular the gravity base values given in SEG special publication International Gravity Measurements (Woollard and Rose, 1963) are evaluated against the most recent set of standardized gravity base values, The International Gravity Standardization Net, 1971 (Morelli et al, 1974). Adjunct IGSN 71 values prepared by the U.S. Defense Mapping Agency Aerospace Center (unpublished) are also used to give a more comprehensive worldwide comparison of values. The results for 787 comparisons of Woollard and Rose (1963) values and IGSN 71 values for the same sites indicate that, in general, there is no difference in gravity standard represented. However, there is a mean absolute datum difference of 14.7 mgal (standard deviation 0.25 mgal). As this value is the same as the difference in the IGSN 71 value for the Woollard and Rose primary base value at Madison, Wisconsin, it corroborates the independent assessment that there is, in general, no difference in gravity standard. However, examination of the data by geographic areas indicates that there are areal anomalous offsets in datum due presumably to undetected tares in the Woollard and Rose values, and also a departure in gravity standard of 0.2 mgal per 1000 mgal in both South America and Europe. As it was possible to establish specific areas in which the Woollard and Rose values are in apparent error relative to the IGSN 71 values as well as the nature and magnitude of the differences in values, it appears possible to use the more extensive worldwide network of Woollard and Rose base values to extend the IGSN 71 network with, in general, an absolute reliability of the order of  $\pm 0.15$  mgal. As many of the existing gravity surveys are not tied to IGSN 71 bases, but are tied to Woollard and Rose bases, much of the existing gravity data in the world not on the new IGSN 71 gravity system could thus be integrated into the new international gravity system with sufficient reliability for most purposes. However, more precise gravity values on an absolute basis are required if gravity is to play a significant role in studying global tectonic movements and geodynamic processes.

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